6TH ICSPP: FUTURE SOLDIER

6th International Congress on Soldiers' Physical Performance

London 2023

Programme Book

Contents

Welcome from the Chairs of the 6th ICSPP London 2023

Welcome to London! On behalf of the ICSPP London Organising Committee we would like to extend a very warm welcome to the 6th ICSPP. The ICSPP London theme, **Future Soldier: Delivering Human Advantage** brings together scientific, military, and medical experts to exchange ideas, present new data, and collectively enable our soldiers to deliver human advantage within the future land warfare domain.

While traditionally focused on the Land domain, you will see that we have representatives from Land, Air, Sea, and Space Commands, which is reflective of the common mission we have in Defence to design and attract the right workforce to deliver a competitive edge, and our need to optimise, enhance, and protect military personnel throughout the operating spectrum. People are rightly recognised as the foundation on which our strategic advantage is built, and it's our job to give them the tools to do so.

ICSPP is the world's leading conference in military human performance, and we are delighted to be here, at ExCel London, alongside the Defence and Equipment Security International (DSEI) and NATO COMEDS.

We are honoured to welcome a number of distinguished Keynote speakers, among them the Chief of the General Staff, General Sir Patrick Sanders; United Kingdom Surgeon General, Major General Tim Hodgetts; Head Army Healthcare, Brigadier Tony Finn; one of the UKs most-cited female AI scientists, Professor Mihaela van der Schaar; Professor of Applied Physiology and Editor-in-Chief of Medicine & Science in Sports & Exercise, Professor Andy Jones; and Professor Ben Goldacre, author of *'Bad Science', 'Bad Pharma'* and *'I Think You'll Find It's A Bit More Complicated Than That*', who will probably tell us all to 'RCT yourself', which is probably good advice.

We are indebted to the previous hosts of ICSPP in Jÿvaskÿla in 2005 and 2011, Boston in 2014, Melbourne in 2017, and Québec City in 2020, for creating this fantastic community, and we hope to do it justice over the next three days. We hope you got some sleep on the plane because the scientific chair intends to work you hard! Have fun!

Julie Greeves OBE Ph.D. & Anna Casey Ph.D.

Welcome from the Host of the 6th ICSPP London 2023

It gives me great pleasure to welcome you to the 6th ICSPP, here in London.

We meet at a time when the importance of international co-operation, intelligence-sharing, and the rapid delivery of battle-winning capabilities cannot be understated. To deliver strategic advantage, we require a workforce that is both Fit to Fight—physically, psychologically, and socially—and Fit for Life in modern society.

I am indebted to all of you here today for travelling to the UK to share your vast expertise, your knowledge of future science and technology, and your commitment to enabling our people to truly deliver a human advantage.

Brigadier Tony Finn MA MRCGP DRCOG DFFP
Head Army Healthcare, British Army

Welcome from the Chair of the 6th ICSPP Scientific Committee

Five keynotes, over 250 free oral and poster communications, and 167 presentations within 30 thematic sessions. The ICSPP 2023 scientific programme is packed! We have been overwhelmed by the volume, quality, and diversity of the submissions. As this year's ICSPP is half a day shorter than previous ICSPPs we have deliberately planned to work you hard with scientific content rolling early into the evenings over the first couple of days; we hope you see this as an opportunity to maximise your time absorbing scientific content. We would like to express our gratitude to our scientific reviewers and the presenters for their submissions; these are the people who have formed the programme we have for you here in London. That leaves us, the scientific committee, with the final word on how we encourage you to tackle ICSPP; we hope to see the frantic movement between and within sessions to catch the latest data or expert opinion and hope to hear the productive—and sometimes challenging— conversations all good scientific meetings should foster. I challenge you to come away questioning our basic assumptions—it is our collective responsibility to advance our field and we hold a responsibility for its reputation in human science.

Thomas J O'Leary Ph.D.

Organising Committee, United Kingdom

Julie Greeves OBE Ph.D.
Co-Chair of 6th ICSPP London 2023

Anna Casey Ph.D.
Co-Chair of 6th ICSPP London 2023

Thomas J O'Leary Ph.D.
Chair of 6th ICSPP Scientific Committee

Sophie Arana Ph.D.
Liaison Officer

Rebecca Knight
Chair of 6th ICSPP Social Committee

Charlotte Coombs Ph.D.

Bethany Moxham

International Committee

Chairs**: Prof Julie Greeves, Dr Anna Casey**

Secretary to 6th ICSPP International Committee: **Mrs Rebecca Knight**

Prof Julie Greeves
UK Army Headquarters

Dr Anna Casey
UK Army Headquarters

Dr Tom O'Leary
UK Army Headquarters

Dr Sophie Arana
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Canadian Armed Forces

Dr Hilde Teien
Norwegian Defence Research Establishment

Dr Graham Fordy
ADA New Zealand

Dr Jace Drain
Australian Defence Force

Dr Jason Lee
National University of Singapore

Dr Henriette Hasselstrøm
Forsvarets Sanitetskommando

Scientific Committee

The 6th ICSPP Scientific Committee extend their grateful thanks to the following scientists who gave their time to conduct peer review of scientific abstracts and / or thematic sessions. All submissions were subject to double-blind review by two assessors against standardised peer-reviewing criteria.

Sophie Arana
Nicola Armstrong
Meaghan E Beckner
Dan Billing
Sam D Blacker
Alex Carswell
Anna Casey
William R Conkright
Charlotte Coombs
Simon Delves
Tim Doyle
Jace Drain
Yoram Epstein
Joanne Fallowfield
Graham Fordy
Karl Friedl
Rob Gifford
Niamh Gill
Julie P Greeves
Herbert Groeller
Jess Gwin
Francois Haman
Henriette Hasselstrøm
Katrina Hinde
Helen Kilding
Rebecca Knight
Kristen J Koltun
Heikki Kyröläinen
Jason Lee
Luana Main
Lee Margolis
Kane Middleton
Bradley C Nindl
Francis O'Connor
Tommi Ojanen
Thomas J O'Leary
Kai Pihlainen
Alex J Rawcliffe
Tara Reilly
Julie Renberg
Hannah Rice
Andrew J Roberts
Andrew Siddall
Hilde Teien
Damien Van Tiggelen
Jani P Vaara
Ella Walker
Graham White
Jodie Wills

Opening

Tuesday 12th September, 09:00 to 09:15

Main Room

Brigadier Antony Peter Finn
MA MRCGP DRCOG DFFP

Head Army Healthcare, British Army

Brigadier Tony Finn was commissioned into the Royal Army Medical Corps as a Professional Qualified Officer in 1998. His first assignment was to Northern Ireland as Regimental Medical Officer for 3 Royal Irish and, by appointment, Senior Medical Officer to Headquarters 3 Infantry Brigade. In this role, he worked closely with the civilian emergency services on medical support to the Drumcree marching seasons and first developed his interest in integrated healthcare systems. He qualified as a General Practitioner in summer 2003, where upon he was promoted to Major, and deployed to Afghanistan as Senior Medical Officer for Operation FINGAL. After a short period as Deputy Senior Medical Officer at the Royal Military Academy Sandhurst, he attended the Initial Command & Staff Course (Land) in 2004. Returning to Camberley he joined the Army Medical Directorate as SO2 Force Development in 2005 before moving to Command B (4) Medical Squadron in 2007. In a busy two years he deployed to Afghanistan for the second time, Kenya and then Iraq. He was promoted to Lieutenant Colonel and attended the Advanced Command and Staff Course in September 2009. Thereafter, he assumed Command of 1 Armoured Medical Regiment and deployed to Afghanistan again, this time as Commanding Officer of the Operation HERRICK 15 Close Support Medical Regiment. Promoted to Colonel in 2012, he returned to the Army Medical Directorate as Assistant Director of Medical Operational Capability. During this time, he was Programme Manager for the Operational Patient Care 2025 programme and led on the development of a Joint concept for integrated Pre-Hospital Care. He refined this integrated concept during his time as Deputy Commander (Medical) for 101 Logistic Brigade and, as Deputy Assistant Chief of Staff (Medical) for the Field Army, he commenced the implementation of the integrated Pre-Hospital Care system across the Army. He was promoted to Brigadier in March 2019 where he then assumed the appointment of Commander of 2nd Medical Brigade, where he was responsible for extending the Integrated Healthcare System and deployed hospital care. Since July 2021 he has been the Senior Health Advisor (Army). He enjoys hill walking and most sports, particularly Rugby and Skiing; he is married to Claire, has two teenage sons (Ryan and Charles) and two energetic Hungarian Vizslas (Otto and Lily).

Keynote 1

Tuesday 12th September, 09:15 to 09:45

Main Room

General Sir Patrick Sanders
KCB CBE DSO ADC Gen

Chief of the General Staff, British Army

Born in Tidworth Garrison military hospital and raised in Norway, Gibraltar and Iraq, General Sir Patrick Sanders was commissioned in 1986 and spent his early service as an Infantry Officer in The Royal Green Jackets in Germany, Norway and the UK. He has commanded on operations in Northern Ireland, Kosovo, Bosnia, Iraq and Afghanistan. His staff appointments have been in operational and strategic roles. He has been a member of the Directing Staff at the Joint Staff College, Pol/Mil adviser for the Commander of Coalition Forces in Iraq in 20034, Colonel Army Strategy, Chief of Defence Staff's Liaison Officer to the US Chairman of the Joint Chiefs of Staff, and Assistant Chief of Defence Staff (Operations) in the MOD. His higher command appointments were 20 Armoured Brigade, the 3rd (UK) Division and the Field Army. He was promoted to General in May 2019 and commanded UK Strategic Command until May 2022. He became Chief of the General Staff in June 2022. He is Colonel Commandant of The Honourable Artillery Company, Honorary Colonel of the Turks and Caicos Islands Regiment and President of the Armed Forces Winter Sports Association. He speaks French and Norwegian, colloquial Spanish and can tell when he is being insulted in Arabic, Pashtun, Dari, Albanian and Serbo-Croat. Married to Fiona Bullen, a successful author, they have made their home in a small Wiltshire village. General Sanders enjoys cycling, all forms of skiing, shooting and whisky. A season ticket holder with their son Kit, he is a martyr to Tottenham Hotspur FC. He dislikes scotch eggs and can't bear Arsenal.

Keynote 2

Tuesday 12th September, 09:45 to 10:30

Main Room

Professor Mihaela van der Schaar
PhD

John Humphrey Plummer Professor of Machine Learning, Artificial Intelligence and Medicine, University of Cambridge

Mihaela van der Schaar is the John Humphrey Plummer Professor of Machine Learning, Artificial Intelligence and Medicine at the University of Cambridge and a Fellow at The Alan Turing Institute in London. In addition to leading the van der Schaar Lab, Mihaela is founder and director of the Cambridge Centre for AI in Medicine (CCAIM). Mihaela is personally credited as inventor on 35 USA patents, many of which are still frequently cited and adopted in standards. She has made over 45 contributions to international standards for which she received 3 ISO Awards. In 2019, a Nesta report determined that Mihaela was the most-cited female AI researcher in the U.K. Mihaela has published more than 600 papers, including 280 journal articles and over 300 conference papers. She has also authored several books and book chapters.

Thematic Sessions 1 to 4

Tuesday 12th September, 11:00 to 12:30

Thematic 1: Measuring and modelling performance and musculoskeletal effects of load carriage

Main Room

Description

Load distribution systems for rucksacks and body armour aim to improve manoeuvrability of the warfighter, and reduce the forces experienced on the shoulders and spine. Yet, it is unclear if these systems are effective in reducing overall musculoskeletal injuries, and what the best methods are to carry these loads under varying and challenging conditions. Solutions to answer these questions lie in our ability to measure and model load carriage of warfighters and systematically measure improvements in performance and mechanics when training regiments have changed. We will provide guidelines for interventions that can more effectively prevent injury and ensure a high level of performance for every individual. Such interventions may include training approaches, evaluation of gear design and method of wear, and approaches to measuring movement and performance in the field.

Background

It is well documented that carrying heavy loads negatively impacts a warfighter's mission performance and musculoskeletal health. It is also becoming clear that personal characteristics (e.g., fitness, sex, experience) affect a warfighter's ability to accommodate such heavy loads leading to reduced physical performance and heightened injury risks. Additionally, the characteristics of the carried equipment (bulk, stiffness, distribution, human-equipment interaction) can exacerbate the negative effects of heavy loads. In addition to traditional motion capture and analysis techniques, digital human models, markerless and inertial-based motion capture methods, and machine learning approaches are increasing our understanding of how load carriage impacts performance and musculoskeletal health. New interventions using wearable devices and exercise programs are also being investigated to improve load carriage capacity that may reduce the influence of personal characteristics. Using an interdisciplinary approach, we can accelerate our understanding of and improve decisions surrounding load carriage systems for warfighters.

Military Impact

Though it is typically recommended that loads do not exceed 25 kg, military service members are often required to carry much higher loads weighing between 40 to 60 kg. Numerous factors affect injury risk and performance, and these factors are often related to load distribution, movement behaviour, and body mechanics. By evaluating all aspects of load carriage using an interdisciplinary approach, we will be able to fill many gaps in our understanding of injury mechanisms and investigate solutions for maintaining performance, increasing overall operational readiness.

Presentations

Chair: *Pinata Sessoms, Naval Health Research Center, USA*

11:00 - 11:05: Introductions and background

Pinata Sessoms, Naval Health Research Center, USA
Ryan Graham, University of Ottawa, Canada

11:05 - 11:17: Quantifying muscle and joint mechanics during military load carriage with musculoskeletal modelling

Anne K Silverman, Colorado School of Mines, USA

11:17 - 11:29: Validation of markerless motion capture for the assessment of joint kinematics and kinetics during military load carriage

Ryan Graham, University of Ottawa, Canada

11:29 - 11:41: Novel data-driven digital human modelling approaches for the predictive assessment of movement under load

Matthew Mavor, University of Ottawa, Canada

11:41 - 11:53: Specificity of male and female responses to military load carriage tasks and preparation

Tim Doyle, Macquarie University, Australia

11:53 – 12:05: Physiological and biomechanical metrics from infiltration and exfiltration marches during a sustained operational exercise

Victoria G Bode, U.S. Army Combat Capabilities Development Command Soldier Center, USA

12:05 – 12:17: Progressive load carriage training reduces musculoskeletal injuries and improves fitness in USMC recruits

Karen R Kelly, Naval Health Research Center, USA

12:17 – 12:30: Questions and discussion

Thematic 2: Soldier combat ensemble considerations for women

Room 1

Description

The development of inclusive equipment and clothing for women is a priority across nations that are part of The Technical Cooperation Programme (TTCP). As such, a collaborative project has been established under TTCP Joint Panel 1 to inform the development of clothing and equipment for women. This session will provide an overview of work being undertaken by Australian, American, British, Canadian, and New Zealand participants of this panel. The aims of this session are to: summarise research focussed on improving the design of clothing and equipment for women; identify knowledge gaps that need to be addressed to improve the design and development of future clothing and equipment; provide design / functional recommendations based on current knowledge and data, and; provide recommendations for the test and evaluation of future equipment and clothing.

Background

Much of the operational equipment / clothing issued and used by servicewomen is either unisex, specifically designed according to the size and shape of men or, has primarily been tested and evaluated on men. These limitations lead to poor fitting equipment / clothing for women, which increases discomfort, limits or degrades task performance, and leads to medical problems. There is emerging evidence that unisex equipment / clothing does not provide adequate fit, form, and function for all.

Military Impact

Previous work has demonstrated the negative impact that poor fitting equipment and clothing has on military task performance and the health of Armed Forces Personnel. Improving the design of equipment and clothing will not only benefit performance and health, but will support diversity, inclusion, and retention initiatives.

Presentations

Chair: *Nicola Armstrong, Defence Science and Technology Laboratory, UK*

11:00 – 11:05: Introduction

Nicola Armstrong, Defence Science and Technology Laboratory, UK

11:05 – 11:20: Female specific versus female inclusive considerations for soldier combat ensemble

Alison Fogarty, Defence Science and Technology Group, Australia

11:20 – 11:40: Female human performance considerations for soldier combat ensemble

Jace Drain, Defence Science and Technology Group, Australia

11:40 – 11:55: Female-inclusive scalable tactical vest: "Narrow STV"

Samantha Saunders, Defence Science and Technology Laboratory, UK

11:55 – 12:10: A collaborative approach to optimise equipment and clothing for a diverse population – A work in progress

Samantha Rodrigues, Defence Technology Agency, New Zealand

12:10 – 12:30: Questions and discussion

Thematic 3: Soldiers at high altitude

Room 2

Description

This session will present research from around the world on humans operating at high altitude. Topics covered will include recent advances in exercise fuel utilisation, cognition, sleep, and physiologic and genomic predictors of acute mountain sickness at high altitude. Recent research conducted at Europe's premier institute for hypobaric chamber research (EURAC) and the United States premier institute for altitude research (USARIEM) will be highlighted. Technological advances that can optimise the health and performance of the soldier rapidly exposed to both simulated and real altitude conditions will be discussed.

Background

Lowlanders rapidly exposed to high altitude experience decrements in physical performance, cognitive performance, and disturbances in sleep. In addition, when lowlanders ascend too high too quickly, they are at risk of developing one or more forms of acute altitude illness: acute mountain sickness (AMS), high-altitude cerebral oedema (HACE), and high-altitude pulmonary oedema (HAPE). The presence of sickness has the potential to result in even more severe decrements in physical performance, cognition, and sleep at high altitude. Large numbers of soldiers may be deployed to high altitude and so the military is faced with questions about how best to prevent sickness as well as optimise performance in mountainous regions. This session will address these concerns.

Military Impact

This session will provide the most recent advances to optimise physical performance at high altitude in terms of fuel mobilisation, preventing decrements in cognitive performance, and identifying the extent of sleep disturbances likely to be encountered by military personnel deployed to various altitudes. In addition, the recent real-time physiologic monitoring and biomarker development of a hypoxic monitoring system will be revealed that can potentially save lives at high altitude.

Presentations

Chair: *Beth A Beidleman, US Army Research Institute of Environmental Medicine, USA*

11:00 – 11:20: Acute high-altitude exposure decreases exogenous glucose oxidation and impairs insulin sensitivity

Lee Margolis, US Army Research Institute of Environmental Medicine, USA [20 minutes]

11:20 – 11:40: Cognitive and physical performance at high altitude following rapid ascent

Michiel van Veelen, Eurac Research, Institute of Mountain Emergency Medicine, Italy

11:40 – 12:00: Sleep loss effects on physiological and cognitive responses to systemic environmental hypoxia

Pierre Fabries, Institute de Rechurche Biomedicale des Armees, Switzerland

12:00 – 12:20: Physiologic and genomic markers to diagnosis and predict acute mountain sickness at high altitude

Beth A Beidleman, US Army Research Institute of Environmental Medicine, USA

12:20 – 12:30: Questions and discussion

Thematic 4: Human-machine teaming

Room 3

Description

The increasing quantity, tempo, and complexity of information available to decision makers at all levels of command presents a challenge to human cognitive capacity. This presents a risk of information overload; critical information being missed—resulting in poor or sub-optimal decisions—or a significant increase in the numbers of people required to handle this cognitive workload. Recent advances in Artificial Intelligence (AI) and its application across a multitude of fields have highlighted the potential impact that this technology could have on how tasks—especially cognitive tasks typically conducted by humans—might change in the future. Consequently, Defence has a significant interest in the use of AI based technologies to address some of the challenges it faces. However, the complex, dynamic, and uncertain nature of military activity, combined with ethical and legal considerations, will require Defence to adopt a human machine teaming approach to the use of AI. This session will provide an overview of a small subset of the research conducted in the field of human-machine teaming from experts working in this area. Presentations of completed and ongoing studies and research in the UK and US will showcase work undertaken through the Bilateral Academic Research Initiative (BARI) as well work undertaken as part of the Defence Science and Technology Laboratory's Future Workforce and Training Programme.

Background

Robotic and AI based technologies offer the potential for an inflexion point in delivering military transformation and advantage. These technologies can perform some tasks more accurately, for longer durations, and in harsher conditions than humans can. However, there are others, where they cannot compete with human flexibility, adaptability, resilience, and creativity. There are also legal, ethical, and safety reasons for humans conducting certain tasks. Consequently, realising the full potential of these technologies will depend on understanding the relative strengths of humans and machines, and how they best function and interact in combination to optimise the effectiveness of the capability as a whole across all use cases and environments. Developing the right blend of human-machine teams—the effective integration of humans and machines and the interaction between them within future systems—is key.

Military Impact

At the core of future military advantage will be the effective integration of humans, AI, and robotics into warfighting systems—human-machine teams—that exploit the capabilities of people and technologies to outperform opponents. Human capabilities and qualities will continue to be central to military tasks across the future operating environment. However, the characteristics of human roles and the nature of their interactions with technologies utilising AI will change. Novel combinations of humans and AI within human-machine teams combined with large numbers of interconnected sensors and soldiers, vehicles, ships, and aircraft will present opportunities across Defence activity; from largely cognitive tasks such as supporting more effective logistics planning or improving intelligence analysis, through to delivering physical effects such as augmenting crewed platforms with semi-autonomous systems to create massed effect.

Presentations

Chair *Jitu Patel, Defence Science and Technology Laboratory, UK*

11:00 – 11:05: Introduction

Jitu Patel, Defence Science and Technology Laboratory, UK

11:05 – 11:15: Human considerations for robotic (intelligent) and autonomous systems

Mike Boardman, Defence Science and Technology Laboratory, UK

11:15 – 11:25: Human machine teaming bilateral academic research initiative (HMT BARI)

Fred Gregory, US Army Research Laboratory, USA

11:25 – 11:35: Measuring individual differences in trust in human-machine teaming

Nick Yeung, University of Oxford, UK

11:35 – 11:45: How can explanations of AI systems skew our beliefs and how do we correct that?

Marko Tesic, University of London, UK

11:45 – 11:55: Working alongside deceptive machines

Stefan Sarkadi, King's College London, UK

11:55 – 12:05: Cognitive models for application of AI

Shaun Lamb, UK Space Command, UK

12:05 – 12:15: Strengthening teamwork for robust operations in novel groups (STRONG)

Ben Files, US Army Research Laboratory, USA

12:15 – 12:30: Questions and discussion

Lunchtime Talk

Tuesday 12th September, 12:45 to 13:15

Main Room

Captain Preet Chandi
MBE

Captain Preet Chandi joined the Royal Army Medical Corps in 2008 as a Combat Medical Technician, she commissioned into the Army Reserves in 2012 and joined the Regular Army in 2016. She is currently serving as a physiotherapist and has completed large scale exercises / deployments in Nepal, Kenya and South Sudan. She completed her Sports and Exercise Medicine MSc in Oct 2021.

In 2022, Preet became the ninth woman in history to ski solo to the South Pole and the first woman of colour to complete a solo expedition on the continent. In 2023, Preet set out on her next adventure, during which, she broke two Guinness World Records for the longest solo unsupported one-way ski expedition by a woman and overall. As part of the endeavour, she covered 922 miles in 70 days.

In 2022, she completed more than four months of school talks in 2022 all over the UK, reaching more than 18,000 students. That same year, she was appointed a Member of the Order of the British Empire (MBE) as part of the Queen's Birthday Honours.

She won the 'Inspirational' and 'Woman of the Year' awards at the inaugural Women in Defence event in October 2022 and received an honorary masters at Derby University in 2022.

Oral Communication 1: Physical Training

Tuesday 12th September, 13:15 to 14:45

Main Room

Chair: *Bradley C Nindl, University of Pittsburgh, USA*

13:15 – 13:30: A pilot study on the efficacy and efficiency of CURATE.AI-guided endurance training

Alexandria Remus [1], Trinh Tran [1], Raymond Wang [1], Ivan Low [1], Dean Ho [1], Jason Lee [1]

[1]*National University of Singapore, Singapore*

Purpose: Improving soldiers' physical performance is a critical goal of military institutions. Conventional training is typically administered as standardised regimens, which can result in suboptimal performance outcomes due to substantial interindividual variability in physiological adaptations to physical training. Artificial Intelligence (AI) technologies have the potential to personalise training programmes in large-scale settings and may yield superior performance outcomes. We compared a novel AI-guided, personalised endurance training programme against conventional training in a pilot trial. **Methods:** Twelve recreationally active men were evenly matched by age, body mass index, body fat percentage, waist circumference, and baseline 2.4 km run time into either the AI or control training group. Our pilot trial required participants to complete four 2.4-km time trials, seven peak oxygen uptake assessments, and five two-week cycles of treadmill interval training over an 18-week period. Participants followed the same standardised interval training programme for the first three training cycles. For the remaining two training cycles, the control group followed a conventional periodisation programme, whilst the AI group followed a personalised programme guided by CURATE.AI, a validated, small-data, dose-optimisation platform that personalises interventions using an individual's own prospectively collected data. The intensity, number of repetitions / session, and total sessions to be completed were standardised for the conventional periodisation programme and determined by CURATE.AI in the AI-guided programme. The magnitude of change in 2.4 km time was used to evaluate the efficacy and training load characteristics were used to evaluate the efficiency of the training programmes. All data were analysed descriptively, and a mixed-model ANOVA corrected for multiple comparisons was used for statistical analyses. **Results:** Efficacy did not differ between the two training programmes ($p = 0.999$) and both groups achieved similar 2.4 km time improvements ($p > 0.9$). However, efficiency between the two training programmes differed ($p = 0.001$) whereby the AI group completed less training repetitions / week, resulting in almost a 35% reduction in training load compared with the control group. **Conclusions:** Our findings demonstrate that CURATE.AI facilitated a more time-efficient endurance training programme, with favourable, if not, equal adaptations observed compared with conventional training. A reduction in training load may lower overtraining and injury risks whilst achieving optimal physical performance outcomes. **Military Impact:** Our pilot study demonstrates that CURATE.AI-guided endurance training shows promise in optimising adaptation and improving physical performance in a time-efficient manner without big data. This approach has the potential to be adopted for large-scale physical training in a military setting to ensure that personnel meet the physical demands required of their duties.

13:30 – 13:45: 12-week maximal strength training period during military service

Tommi Ojanen [1], Mikko Rastas [2], Jani P Vaara [2], Kai Pihlainen [3], Heikki Kyröläinen [2]

[1]Finnish Defence Research Agency, Finland
[2]National Defence University, Finland
[3]Defence Command, Finland

Purpose: Modern warfare requires soldiers to perform physically very demanding tasks, like lifting and carrying heavy equipment, moving long distances in rough terrains, and manoeuvring through buildings in urban environment. Thus, a modern soldier needs not only good aerobic endurance, but also high level of neuromuscular performance to be able to effectively respond to various operational demands. Therefore, it is important to optimise physical performance by optimal physical training. The aim of the present study was to investigate the impact of maximal strength training on soldier's physical performance during a 12-week training period. **Methods:** 40 voluntary soldiers were divided into two training groups: experimental (EXP) (n = 21, 20 ± 1 y, 1.78 ± 0.04 m, 69.1 ± 7.6 kg) and control (CON) (n = 19, age 20 ± 1 y, 1.83 ± 0.04 m, 77.3 ± 7.8 kg). Both groups had equal amount of physical training during the intervention: the EXP group trained maximal strength and the CON group performed regular military physical training for 12 weeks. Body composition, maximal strength and power of the upper and lower extremities, and casualty evacuation test were measured four times (PRE, MID1, MID2, and POST). Analysis of variance was conducted in R for differences and correlations between timepoints and groups. **Results:** The EXP group showed increase in upper body power (PRE vs MID1 6.4 ± 6.3%, $p < 0.01$), in upper body maximal isometric strength (PRE vs MID1 6.3 ± 5.6%, $p < 0.01$), in deadlift (PRE vs MID1 10.3 ± 6.9%, $p < 0.01$; PRE vs POST 14.9 ± 9.2%, $p < 0.01$), in bench press (PRE vs MID1 11.8 ± 6.2%, $p < 0.01$; PRE vs POST 14.7 ± 11.0%, $p < 0.01$), and decrease in evacuation test time (PRE vs MID1 −17.4 ± 12.9%, $p < 0.01$), whereas CON showed only significant increase in bench press (PRE vs MID1 6.3 ± 7.5%, $p < 0.01$; PRE vs POST 10.4 ± 12.2%, $p < 0.01$). **Conclusions:** Maximal strength can be improved or, at least, maintained during military service with periodised strength training program among young soldiers. It seems that high physical strain induced by military training influences maximal strength development more in the lower body than in the upper body, respectively. Maximal strength training should be a part of soldiers' weekly training, with focus on intensity, quality, and individualisation of training. **Military Impact:** Maximal strength, large fat-free mass, and high muscle mass play an important role in enhanced task specific performance, such as casualty evacuation. Therefore, they are important factors that should be taken into consideration when planning training programs during military service.

13:45 – 14:00: Generating resilience to injuries through training (GRIT)

Eric Robitaille [1], Vanessa Larter [1], Scott Heipel [2], Tara Reilly [2], Etienne Chasse [2], Hans Christian Tingelstad [2]

[1]Canadian Forces Health Services Group, Canada
[2]Canadian Forces Morale & Welfare Services, Canada

Purpose: Previous studies have shown that modified physical training programs implemented during basic military training courses can reduce musculoskeletal injuries and their associated burdens. It is unknown if modified physical training programs could demonstrate the same results during basic infantry courses and be implemented without compromising operations. The purpose of this study was to determine the feasibility of implementing an evidence-based physical training program compared with a control during a basic infantry training course and compare their effectiveness on measures of musculoskeletal injuries and their associated burdens. **Methods:** Basic infantry candidates awaiting course between 01-April-2019 and 31-March-2020 were invited to participate, while those releasing from the military, awaiting occupational transfer or having > 5 medical employment limitation days were excluded. Consenting participants were allocated to an infantry course prospectively scheduled to host either the evidence-based physical training program or a control. The evidence-based physical training program adapted modified physical training strategies from previous studies reporting reduced musculoskeletal injuries during basic military training and was supervised by certified fitness professionals, while the control was at the discretion of basic infantry instructors. All musculoskeletal injuries reported by participants during the basic infantry course were diagnosed by a licensed physician or physician assistant. Study feasibility was operationalised with quantitative outcomes related to recruitment, outcome measurement, and intervention processes, while qualitative outcomes related to operations were determined by a group of local stakeholders. **Results:** With the exception of intervention duration, which was limited due to operational factors, all feasibility outcomes were met including a recruitment rate of 171 / 203 (84.2%) and an intervention adherence of 126 / 144 (87.5%). Stakeholders reported that the evidence-based physical training program implementation was feasible and posed a manageable demand on resources without compromising operations. Evidence-based physical training program participants reported 68% fewer overuse musculoskeletal injuries, 296 fewer medical employment limitation days, and 11 fewer attritions than control participants. Conclusions: An evidence-based physical training program was feasible to implement on a basic infantry training course, and resulted in fewer musculoskeletal injuries, medical employment limitation days, and attrition. **Military Impact:** Modern physical training practices designed to minimise musculoskeletal injuries and their associated burdens may be successfully implemented during basic infantry courses without compromising operations and may offer the same benefits for intermediate/advanced combat arms courses.

14:00 – 14:15: Effects of high-intensity functional training on serum testosterone, cortisol and IGF-1 levels during military service

Joonas Helén [1], Heikki Kyröläinen [1], Tommi Ojanen [2], Kai Pihlainen [3], Jani P Vaara [1]

[1]National Defence University, Finland
[2]Finnish Defence Research Agency, Finland
[3]Finnish Defence Forces, Finland

Purpose: While high-intensity functional training has been reported to be beneficial for the development of physical performance in soldiers, hormonal responses to such training in military

environments are not well documented. Testosterone, cortisol, and IGF-1 are considered useful markers for monitoring stress responses and recovery status in soldiers. The purpose of this study was to investigate the effects of high-intensity functional training on serum testosterone, cortisol, and IGF-1 concentrations during military service. **Methods:** Voluntary male conscripts (n = 127) were divided into two groups for the 19-week training intervention study. Training for the experimental group (EXP: n = 64) included high-intensity functional training using sandbags, kettlebells, and body weight. The control group (CON: n = 63) trained according to the current practice, which focused on ball games, running, and calisthenics. The total volume of training was 46 and 42 h in EXP and CON, respectively. Overnight fasting blood samples were drawn before (PRE), at week 10 (MID), and after (POST) the training period. Linear mixed-effects models and Tukey's post-hoc tests were used for between- and within-group comparisons. **Results:** Testosterone increased in both groups between PRE–POST (EXP: 28 ± 29%, $p < 0.001$; CON: 44 ± 48%, $p < 0.001$). A significant group × time interaction occurred for cortisol ($p < 0.05$) and IGF-1 ($p < 0.001$). Cortisol increased in CON between PRE–MID (17 ± 30%, $p < 0.001$), but returned to baseline level at POST. Cortisol remained unchanged in EXP. IGF-1 increased in CON (17 ± 22%, $p < 0.001$) between PRE–POST, while no change was observed in EXP. **Conclusions:** High-intensity functional training had no negative impact on testosterone, cortisol, and IGF-1 levels during military service when compared with traditional physical training, suggesting that the total physiological strain was not excessive. In addition, high-intensity functional training was more effective than traditional training in improving physical fitness in this study (Helén et al., 2023, J Strength Cond Res, epub ahead of print). Therefore, high-intensity functional training can be recommended for soldiers. **Military Impact:** High-intensity functional training is an effective and feasible training method for military population and seems to be well-tolerated.

14:15 – 14:30: Group and individual endogenous hormonal responses to acute resistance exercise and load carriage workouts

Barney Wainwright [1], Daniel Snape [1], David Woods [1], Theocharis Ispoglou [1], Anna M Nicholson-Little [1], Samantha Saunders [2], John P O'Hara [1]

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Purpose: To evaluate and compare the acute group and individual endogenous hormone responses to three resistance exercise workouts and two load carriage workouts. Understanding hormone responses specific to military settings may enhance training optimisation in the future. **Methods:** Eighteen resistance exercise-trained male civilians (age: 19 to 38 y, mean 24.9 y) completed five experimental workouts and a control condition in a randomised order; three resistance exercise workouts (cluster, hypertrophy, endurance), two load carriage (90-min constant pace [CO-LC] or 6 × 8-min intervals [IT-LC], both carrying a rucksack with 25% body mass) workouts, and a control condition (60-minutes of rest). Venous blood was drawn before, immediately post workout, and 30-min and 24-h post workout. Testosterone (T), free testosterone (fT), growth hormone (GH), dehydroepiandrosterone sulphate (DHEAS), androstenedione

(ANST), and insulin-like growth factor 1 (IGF-1) concentrations were subsequently analysed via liquid chromatography-mass spectrometry. Group responses were evaluated using two-way ANOVAs with Tukey's post-hoc analysis. The standardised standard deviations of the pre-post change scores (SDIR) were calculated to identify the presence of individual responses (Hopkins, 2015, J Appl Physiol, 118, 1444–1446). **Results:** Group responses were observed despite large individual variations. T concentrations increased in response to hypertrophy ($p < 0.001$) and CO-LC ($p = 0.02$) workouts; fT concentrations increased in response to CO-LC ($p < 0.001$) and decreased following the hypertrophy ($p = 0.035$) workout; ANST concentrations increased in response to CO-LC ($p = 0.007$); GH increased following hypertrophy ($p = 0.004$), endurance ($p = 0.04$), IT-LC ($p < 0.001$), and CO-LC ($p < 0.001$) workouts; IGF-1 increased in response to the endurance ($p = 0.018$) workout. The SDIR effect size thresholds of extremely large (T, GH, DHEAS) and very large (T, GH, DHEAS, ANST, IGF-1) were achieved, representing an individualised pattern of hormone production in response to the different resistance exercise and load carriage workouts. **Conclusions:** The presence of within-workout variations in the hormonal responses to all workout types suggests that the mean group responses may not reflect the response experienced by all participants, and that the hormonal anabolic response differs between individuals. The group responses and within-workout variation suggest that a wide panel of endogenous hormones should be measured to provide clarity on the hormonal anabolic response to different types of training stimuli at the individual level. **Military Impact:** The hormonal anabolic response to training type differs between individuals. This research provides support to further investigate whether training interventions based upon an individualised anabolic hormone response to acute exercise leads to improved physical outcomes.

Oral Communication 2: Musculoskeletal Injury and Physiology

Tuesday 12th September, 13:15 to 14:45

Room 1

Chair: *Joanne L Fallowfield, Institute of Naval Medicine, UK*

13:15 – 13:30: Disorganized Achilles tendon structure is related to lower neuromuscular ability and ankle impairments in recruits

Nili Steinberg [1], Michal Shenhar [1], Aharon S Finestone [2], Jeremy Witchalls [3], Gordon Waddington [3], Omer Paulman [4], Gali Dar [5]

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[2]Shamir Medical Center, Israel
[3]University of Canberra, Australia
[4]Israel Defense Forces, Israel
[5]University of Haifa, Israel

Purpose: Infantry personnel with Achilles tendon (AT) structure disorganization have shown to be at increased risk for several types of ankle injuries. However, the explanation for this is not clear. One possibility is that neuromuscular performance and ankle function impairment are involved in the injury mechanism, and that AT structure disorganization is a confounder. The aim of this study was to assess the relationship between disorganized AT structure, ankle impairments and neuromuscular performance. **Methods:** The AT of 360 combat Soldiers recruited in 2022, were examined using ultrasound tissue characterization (UTC) to identify soldiers with disorganized AT structure (≥ 8.6% echo-type III fibres). Neuromuscular performance abilities assessed included proprioception ability (AUC), heel-rise test (n), postural balance (cm), and an agility test (n). The soldiers were assessed for reported sprains, mechanical instability and perceived instability. **Results:** Soldiers with ≥ 8.6% echo-type III fibres (disorganised fibres) had significantly lower ability in the heel-rise and hopping tests (33.6 ± 18.1 vs 49.9 ± 28.9, $p = 0.001$; 5.39 ± 2.12 vs 6.16 ± 1.90, $p = 0.002$, respectively). No significant differences were found in the other neuromuscular performance tests. Using a receiver operating characteristic analysis, soldiers with ≥ 8.6% echo-type III fibres, the area under the curve for the heel-rise test (0.741) was higher compared with proprioception, agility, and postural balance abilities (0.579, 0.578, and 0.601, respectively). Moreover, soldiers with disorganized AT structure had a higher prevalence of mechanical instability and reported more sprains than soldiers with < 8.6% echo-type III fibres (organized structure) (6.7% vs 4.9%; 12.4% vs 7.6%, respectively) ($p = 0.05$). **Conclusions:** Disorganized AT structure is related to ankle impairments and to decreased performance abilities that involve the triceps surae muscles and hopping agility ability. **Military Impact:** Clinicians should consider that many soldiers who are medically discharged from basic training do so due to orthopaedic injuries in general, and ankle related injuries. Moreover, inferior tendon quality at the onset of military service might serve as an important element when dealing with future injuries; as such, pre-recruitment screening of the AT structure, ankle impairments, and neuromuscular abilities, especially in high-intensity infantry programs, is of utmost importance. This screening could increase the identification of at-risk soldiers, enabling targeted modifications of the training program combined with the implementation of treatment and / or preventive strategies.

13:30 – 13:45: The association between neuromuscular performance and chronic ankle instability in pre-recruitment infantry soldiers.

Jeremy Witchalls [1], Nili Steinberg [2], Michal Shenhar [2], Gordon Waddington [1], Gali Dar [3], Omer Paulman [4], Aharon S Finestone [5]

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[2]Wingate Institute, Israel
[3]University of Haifa, Israel
[4]Israel Defense Forces, Israel
[5]Shamir Medical Center, Israel

Purpose: Chronic ankle instability (CAI) is identified by the presence of various impairments—including functional and mechanical instability—that may exist independently or in combination with other impairments. Our aim was to examine the prevalence of various subgroups of CAI impairments, and their effect on neuromuscular performance in pre-recruitment combat soldiers. **Methods:** A cross-sectional observational study was undertaken in a military basic training setting. The study participants were 364 pre-recruitment combat soldiers (aged 18 to 21 y). The soldiers were assessed for CAI impairments via a range of tools (CAIT questionnaire, previous ankle sprain questionnaire, and clinical ankle instability assessment using manual tests) that were then combined into different subgroups of CAI impairment. The participants were screened for neuromuscular performance on their dominant and non-dominant legs during the first week of their combat military service. Assessments included proprioceptive ability, hexagon test, heel rise test, and Y-balance test. **Results:** Participants reported a history of previous ankle sprains in their dominant leg (18.4%) and non-dominant leg (20.5%). Low CAIT scores were seen in 27.8% and 29.2% of the participants, and positive clinical signs were seen in 9.9% and 8.8% of the participants, for their dominant and non-dominant leg, respectively. ANOVA showed significant differences between the different impairment subgroups, with participants with no CAI scoring better than those with different mixtures of CAI impairments for the mean proprioception ability scores for the dominant ($F = 6.943$, $\eta_p^2 = 0.080$, $p < 0.001$) and non-dominant leg ($F = 7.871$, $\eta_p^2 = 0.090$, $p < 0.001$) and the mean heel rise scores ($F = 4.884$, $\eta_p^2 = 0.055$, $p = 0.001$) for the non-dominant leg. **Conclusions:** A high prevalence of CAI was identified among participants, and soldiers with CAI presented with reduced abilities compared with soldiers without CAI. Soldiers defined in subgroups represented by a single CAI impairment exhibited different neuromuscular deficits than those defined in subgroups with different single impairments or with more than one impairment. **Military Impact:** Clinicians, medical staff, and military commanders should be aware of the high prevalence of CAI among recruits and of their reduced neuromuscular abilities, that could increase risk of future injuries. Identifying individuals with these risk factors for future injuries will enable them to receive prevention programs that are targeted at modifying the deficits, and protection from higher risk training activities until these are corrected. This has significant potential benefit for retention of recruits within training and with the original trainee peer group, with benefits for military expenditure and recruit wellbeing.

13:45 – 14:00: Daily rating of perceived exertion, wellness, and injury risk during Army basic military training

Neil Gibson [1], Jace Drain [2], Penny Larsen [1], Sean Williams [3], Scott Michael [1], Herbert Groeller [1], John Sampson [1]

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[3]University of Bath, UK

Purpose: Continuously monitoring responses to the stressors of basic military training (BMT) may offer researchers and practitioners a method to determine specific periods when recruits may be at a greater risk of injury throughout BMT. This study therefore aims to investigate associations between daily self-reported rating of perceived exertion (RPE), wellness, and injury risk during Australian Army BMT. **Methods:** In this prospective cohort study, Army recruits (n = 604, men = 510; women = 94; age: 22 ± 5 y [range: 17 – 55 y]) self-reported daily RPE and wellness (soreness, mood, energy, and stress) each evening using a custom-designed questionnaire and reported daily health problems using a modified Oslo Sports Trauma Research Centre Questionnaire on Health Problems. Questionnaires, presented as a booklet consisting of repeated questionnaires for the week (7 days), commenced on day 2 and continued until the day before march-out parade in week 12 (day 79). Within-subject Z-scores were calculated for RPE and wellness measures and only injury related health problem reports were included in the analyses. Generalised linear mixed-effects models were used to model associations between daily RPE, wellness, and injury risk. **Results:** A non-linear relationship ($p < 0.001$) was observed between changes in RPE (Z-score) and the predicted probability of injury. Negative linear relationships ($p < 0.001$ - 0.002) were observed between wellness measures and predicted probability of injury. For a one-unit (Z-score) increase (i.e., 'improvement') in soreness (odds ratio [95% confidence intervals], 0.90 [0.85 - 0.96]), mood (0.89 [0.84 - 0.94]), energy (0.87 [0.82 - 0.92]), stress (0.86 [0.81 - 0.91]), and overall wellness (0.86 [0.81 - 0.92]) the odds of injury significantly decreased. **Conclusions:** Daily monitoring of RPE and wellness during BMT may provide researchers and practitioners with evidence in relation to injury risk, however, the magnitude of the effects reported along with the costs associated with daily monitoring should be considered. **Military Impact:** The results indicate that self-report tools may offer some utility in managing training stress and injury risk in recruits undertaking basic military training.

14:00 – 14:15: Association between embedded injury prevention experts in U.S. Army initial entry training and early discharges from service

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Purpose: To assess the impact of injury prevention experts (IPEs), specifically athletic trainers and strength and conditioning coaches, embedded in U.S. Army initial entry training (IET) on likelihood of early discharge from service (i.e., within the first six months) for musculoskeletal (MSK) condition-related reasons. **Methods:** A retrospective cohort study was performed on 198,166 Soldiers who began IET during 2014 – 2017 (age = 21 ± 3 y; body mass index [BMI] = 24.4 ± 3.5 kg·m2) by using monthly administrative, medical, and readiness records from the medical assessment and readiness system database housed at Womack Army Medical Center (Fort Bragg, North Carolina, USA). Early discharge from service was defined as within six months of beginning IET, since most Soldiers complete IET by then. All four IET sites employed IPEs from 2011 - 2017 except for two sites during April 2015 - November 2015. Soldiers who began IET at these two sites during these times were categorised as not having IPE exposure. All others were categorised as having IPE exposure. A Cox proportional-hazards model was used to assess relationships between IPE access and early discharge from service while controlling for the influence of sex, age, race, tobacco use, BMI, military occupational specialty, and training site. **Results:** 14,094 (7.1%) of the 198,166 Soldiers did not have exposure to IPE during IET, and of these, 391 (2.8%) were discharged early due to MSK related reasons. Among the 184,072 Soldiers with IPE exposure, 1,861 (1.0%) were discharged early. Soldiers without access to IPEs during IET were 1.3 times more likely to be discharged early from service for MSK related reasons when compared with Soldiers with access to IPEs during IET (adjusted hazard ratio [95% confidence interval] = 1.38 [1.22, 1.55], $p < 0.001$). **Conclusions:** Embedding IPEs in U.S. Army IET is associated with fewer early service discharges for MSK related reasons. Further research is needed to establish best practices for embedding IPEs in training settings within the U.S. Army and Department of Defense. **Military Impact:** MSK conditions commonly occur during U.S. Army IET, which increases the likelihood of Soldiers separating from service by the end of training. To address this problem, the U.S. Army has embedded IPEs, specifically athletic trainers and strength and conditioning coaches, into IET. However, little is known about the impact IPEs have on early discharge from service. Establishing and disseminating best practices for IPEs will help promote their beneficial impact on operational readiness throughout the U.S. Army and Department of Defense.

14:15 – 14:30: Perceived health and self-regulation are associated with on-time graduation: the Initiation of Marine Physiological Assessment of Combat Training (IMPACT) study

Sarah J de la Motte [1], Emily A Ricker [1], Amelia S Barrett [1], Carl W Goforth [1]

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Purpose: We conducted the Initiation of Marine Physiological Assessment of Combat Training (IMPACT) study to prospectively evaluate the influence of biopsychosocial characteristics (e.g., sex, stress, resilience, support, functional movement, performance strategies) and medically documented MSK-I during training on successfully completing the Basic Officer Course (BOC) on-time. **Methods:** More than 80 biopsychosocial characteristics were evaluated in Marine officers entering BOC (female: 156, male: 1174) using a combination of validated questionnaires, self-report items, and functional movement evaluations. Medically documented MSK-I during training and graduation status (on-time vs dropped / discharged) were obtained via military tracking systems. Univariate analyses compared individual traits based on sex, MSK-I during training, and on-time graduation. Following Bortua variable reduction, modelling procedures that incorporated exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and structural equation modelling (SEM) with logistic regression were used to comprehensively distil traits, including sex, associated with on-time graduation. EFA and CFA were used to identify and confirm latent constructs (patterns of inter-relationships amongst variables) in our data. EFA yielded 15 latent variables, six of which were confirmed by CFA. Five latent variables comprised combinations of several psychosocial measures, whereas one included MSK-I during training, self-reported pain, age and functional movement at BOC entry. Latent constructs were entered as independent variables into SEM modelling, along with sex and additional covariates (e.g., training company). **Results:** On-time graduation did not vary by sex (female: 80%, male: 83%, $p = 0.38$). Medically documented MSK-I during training varied by sex (female: 57%, male: 33%, $p < 0.001$) and was higher in those who did not graduate on time (54% vs 32%, $p<0.001$). Primary findings from SEM showed three latent constructs, each of which comprised several psychosocial measures, were associated with increased odds of on-time graduation: 1) greater perceived health (OR [95% CI] = 2.05 [1.25, 3.34], $p = 0.004$); 2) self-regulation during military training and evaluations (1.60 [1.25, 1.27], $p < 0.001$); and 3) bio-behavioural health state (1.05 [1.02, 1.09], $p = 0.006$). Neither sex nor the latent construct including MSK-I and functional movement were associated with odds of on-time graduation ($p = 0.26$ to 0.34). **Conclusions:** Results suggest greater self-perceived health and self-regulation during training and evaluations positively influenced on-time BOC graduation. **Military Impact:** To our knowledge, this study is the first to comprehensively evaluate biopsychosocial characteristics of on-time BOC graduates. Psychosocial factors appear play an important role in training outcomes and should continue to be included in military research.

14:30 – 14:45: Pain sensitivity and processing in high performance combatant craft crewmen: an early indicator of injury risk?

Karen R Kelly [1], Daniel Bennett [1], Andrea Givens [1], Brenda Niederberger [1], David Berry [2], Samuel Ward [2], Bahar Shahidi [2]

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Purpose: Pain sensitivity and tolerance has been shown to be altered in individuals with chronic pain, and pain modulation efficacy has been shown to be predictive of development of chronic pain after an acute injury. Thus, the purpose of this effort was to measure pain sensitivity and threshold in high performance combatant crewmen (HPCC). **Methods:** HPCC ($n = 62$) and infantry marines (comparative control, $n = 23$) were recruited. Demographic characteristics, low back pain related disability (ODI), and neck pain related disability (NDI) were collected via questionnaire. Pressure pain thresholds (a measure of pain sensitivity) were obtained using pressure algometry of the cervical spine on the dominant side, applied 2 cm lateral to the C3 spinous process, and averaged across three trials. Conditioned pain modulation (a measure of efficacy of pain inhibition) was measured using a cold pressor test and calculated as the difference in pain pressure thresholds between submersion of the non-dominant hand in a 23°C water bath and an 8°C water bath, averaged across two trials each, and divided by the pre-test threshold. **Results:** Participants (age: 28.2 ± 5.5 y; length of service: 7.4 ± 5.7 y) reported on average minimal to moderate low back and neck pain related disability (ODI score: 16.9 ± 14.8%; NDI score: 8.8 ± 10.9%). HPCC demonstrated lower mechanical pain thresholds in the back (496.3 ± 273.3 kPa) and neck (292.5 ± 147.7 kPa) and higher mechanical thresholds in the forearm (control site: 360.9 ± 203 kPa) compared with literature-based values for healthy male civilians (back: 882.6 ± 264.8 kPa, $p < 0.001$; neck: 349.0 ± 76.0 kPa, $p < 0.001$; forearm: 196.0 ± 78.0 kPa, $p = 0.005$). Marines had similar differences with civilian controls for the mechanical pain thresholds for lower back (514.6 ± 231.7, $p < 0.001$), neck (305.3 ± 163.3, $p = 0.168$), and forearm (399.9 ± 175.6, $p = 0.003$). Both HPCC and marines demonstrate lower inhibitory efficacy (8.3% and 17.6% respectively) compared with civilian controls (45.0%). HPCC had significantly lower sensitivity to cold water compared with civilians (13.2 vs 5.2 s, $p < 0.001$) and marines (13.2 vs 11, $p = 0.001$). **Conclusions:** HPCC have higher pain sensitivity in the back and neck, but lower pain sensitivity in the forearm compared with data from age-matched civilian males, which may be reflective of local sensitisation of the spine resulting from low-grade back and neck injury. HPCC were less sensitive to thermal stimuli compared with civilians, possibly due to job-specific training adaptations. The reduced ability to inhibit pain compared with healthy civilians, which may reflect changes in neurophysiological pain processing resulting from chronic pain or injury. **Military Impact:** Pain response is an early sign of injury and / or a high risk for developing chronic symptoms after acute musculoskeletal injury. Identification of individuals with abnormal pain response could lead to early intervention to decrease the likelihood of developing chronic pain.

Oral Communication 3: Cognitive Performance

Tuesday 12th September, 13:15 to 14:45

Room 2

Chair: *Graham Fordy, ADA New Zealand, New Zealand*

13:15 – 13:30: Cognitive genomics: mapping the genetic architectures of cognitive fitness

Scott Richard Clark [1], Liliana Ciobanu [1], Lazar Stankov [2], Muktar Ahmed [1], Andrew Heathcote [3], Eugene Aidman [4]

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[2]University of Sydney, Australia
[3]University of Newcastle, Australia
[4]Defence Science & Technology Group, Australia

Purpose: A transdisciplinary expert consensus is emerging on core dimensions of cognitive fitness (Aidman, 2020, Front Hum Neurosci, 13, 466; Albertella et al., 2022, Front Psych, 1017675) underpinning performance under pressure and sustained resilience in mission-critical occupations. How modifiable the components of cognitive fitness are, is critical to shaping cognitive assessment, training, and augmentation in the military. Our study addresses their modifiability by investigating the genetic underpinnings and heritability of cognitive abilities using advanced biostatistics. **Methods:** UK Biobank (UKB) data from healthy participants who completed all UKB's nine cognitive tests ($n = 3,425$) were analysed with Structural Equation Modelling, revealing three latent factors informed by the Cattell–Horn–Carroll model—visuospatial reasoning, verbal-analytic reasoning, and processing speed (Ciobanu et al., 2023, Front Psych, 14, 1054707). We then used gold standard genome-wide association (GWAS) and a machine learning approach, Weighed Single Nucleotide Polymorphism (SNP) Correlation Network Analysis (WSCNA), to identify genomic and functional correlates of each factor. **Results:** In GWAS, no SNPs reached significance at $p < 5 \times 10{-}8$, however, 121 SNPs (41 for visuospatial reasoning, 21 for verbal-analytic reasoning, and 59 for processing speed) were suggestive of association at $p < 1 \times 10\text{-}5$. The WSCNA showed that latent factor-related SNPs clustered in biologically relevant modules explaining 9.8% of variance in visuospatial reasoning, 12.4% in verbal-analytic reasoning, and 11.1% in processing speed. In-silico analysis of downstream biological effects suggested that these genes are expressed primarily in cortical and subcortical brain regions and seem to be involved in factor-specific molecular pathways. **Conclusions:** Our findings suggest that the heritability of fluid intelligence is relatively small, and that it is possible to identify specific genetic markers and biological pathways contributing to each latent factor, suggesting a role for genomics in understanding the biological basis of cognitive fitness. **Military Impact:** Given the widely ranging demands of defence roles, the systematic assessment of different types of fluid reasoning may inform selection processes. Genomic markers may help estimate the trainability of specific cognitive functions and inform interventions to maintain cognitive fitness in military personnel.

13:30 – 13:45: Relationship between habitual caffeine consumption, attentional performance, and individual alpha frequency during total sleep deprivation

Michael Quiquempoix [1], Catherine Drogou [1], Damien Léger [2], Mounir Chennaoui [1], Danielle Gomez-Merino [1], Fabien Sauvet [1]

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Purpose: Our aim was to assess effects of acute caffeine intake on cognitive vulnerability and brain activity during total sleep deprivation (TSD), considering habitual caffeine consumption. **Methods:** Thirty-seven participants (15 women, age 18 to 55 y, body mass 66.9 ± 4.1 kg) were evaluated in a double-blind, crossover laboratory protocol (including a baseline day beginning at 07:00 (D1), a total sleep deprivation (TSD) day beginning on D1 at 23:00 until 21:00 at D2, followed by sleep recovery). Participants consumed either caffeine (2.5 mg·kg-1 of powder in a decaffeinated beverage) or placebo (decaffeinated beverage), twice a day (at 08:30 and 14:30) on D1 and D2, with a 2-week washout period. Vigilant attention was evaluated every six hours during TSD using the Psychomotor vigilance test (PVT). The Epworth Sleepiness Scale (KSS) was filled in and the EEG recorded during PVT at 09:15 on D1 and D2, corresponding to 2 and 26 h of prolonged wakefulness. The individual alpha frequency (IAF) was obtained by averaging the AFs over all 19 electrodes. The influence of habitual caffeine consumption was analysed by categorising participants into low, moderate, and high consumers (0 to 50, 51 to 300, and >300 mg·d-1, respectively). Values of PVT RT, KSS, IAF, and EEG band power were analysed using a linear mixed model including fixed effects for awakening duration (repeated measures ranging from 2 to 32 h), acute treatment (caffeine or placebo, repeated measure), and habitual caffeine consumption (non-repeated measure). Secondly, effects of caffeine consumption groups were analysed using a mixed linear model including caffeine consumption groups, awakening (repeated measure), and a random effect on age. **Results:** RT was significantly higher from 14 h to 32 h compared with 2 h of continuous time awake ($t = -3.45$, $p = 0.001$; $t = -9.69$, $p < 0.001$; $t = -13.14$, $p < 0.001$; $t = -10.21$, $p < 0.001$, respectively), lower in caffeine compared with placebo ($t = -5.12$, $p < 0.001$), and lower for low habitual caffeine consumers compared with moderate ($t = -2.35$, $p = 0.015$) and high consumers ($t = -3.01$, $p = 0.049$). The TSD-related increase in EEG power was attenuated by acute caffeine intake independently of habitual caffeine consumption, and individual alpha frequency (IAF) was lower in high consumers. The IAF was negatively correlated with KSS (rm_corr = −0.437, $p < 0.001$). Moreover, correlation analysis showed that the higher daily caffeine consumption, the higher RT and the lower IAF. **Conclusions:** High habitual caffeine consumption decreases attentional performance and alpha frequencies, decreasing tolerance to sleep deprivation. **Military Impact:** Recommendations regarding caffeine consumption are needed to limit degradation of attentional vigilance capacities during total sleep deprivation.

13:45 – 14:00: Towards digital and standardised measures of closequarters battle tactical performance using virtual reality

Annemarie Landman [1], Charelle Bottenheft [1], Matthijs Koedijk [1], Yvonne M Fonken [1], Minke Geerts [1], Olaf Binsch [1]

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Purpose: The purpose of this study was to investigate whether different aspects of close-quarters battle (CQB) tactical performance can be measured in an objective and digitizable

manner. Digital performance measures can support instructors in evaluating and in providing feedback. **Methods:** Special Operations Forces (SOF) operators (n = 16) and regular infantry soldiers (n = 22) individually performed CQB scenarios using a Virtual Reality (VR) training platform. The VR system enabled free movement using a full-body motion tracking suit and featured immersive role-playing with an actor playing a friendly or hostile character. With subject-matter experts, a list of observable performance-related actions was predefined. Other objective measures were "time until room clear" and "shooting reaction time". Subjective ratings of the infantry group's tactical performance were obtained from subject-matter experts. The VR test and objective performance measures were evaluated by comparing the two groups, and by determining relationships between the objective and subjective performance measures. **Results:** The SOF group performed the scenarios significantly faster (30%, $p < 0.001$), and made better shooting decisions ($p = 0.053$). The subjective ratings of performance were significantly predicted by observed manoeuvring actions ($p = 0.005$) and time until room clear ($p = 0.008$). Both groups evaluated the quality of the scenarios as 5 on a 1-to-7-point scale. **Conclusions:** The most promising objective measures of CQB tactical performance were the manoeuvring actions and performance speed. Few performance differences were found between SOF and regular infantry, suggesting that objective measures of performance would likely need to be better adapted to different target populations. **Military Impact:** CQB manoeuvring, and performance speed can be measured digitally, and visualised during and after training exercises to provide relevant insights into tactical performance to instructors as well as trainees. Our results show that certain manoeuvring actions can be predefined as correct and incorrect, suggesting that such classification of performance can also be performed digitally. VR provides a relatively low-cost platform with the potential to obtain such measures digitally, while also allowing for reviewing performance during debrief.

14:00 – 14:15: Combined cognitive and physical training; a more efficient and tolerable means of enhancing cognitive and physical performance: preliminary findings from a randomised controlled trial with young healthy adults

Amanda Scott [1], Kristy Martin [1], Keely McDicken [1], Joe Northey [1], Ben Rattray [1], Philip Temby [2]; Alison Fogarty [2], Amit Lampit [3]

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Purpose: Research supports the use of concurrent cognitive and physical training for improving cognition and fitness in older adults. However, as yet, it is unclear if these benefits apply to younger people and if the observed improvements are superior to separate cognitive and physical training. This study sought to investigate the effectiveness of concurrent training for improving cognitive and physical performance outcomes in young healthy adults. **Methods:** 52 participants (29 female, 27 ± 6 y, baseline VO_{2peak} 34.9 ± 9.4 mL·kg-1·min-1) had been recruited for a 12-week investigator blinded randomised controlled trial. Participants were randomised to either physical training only (PA), concurrent cognitive and physical training

(PACog), or separate cognitive and physical training (PA&Cog). The intensity of the physical training was prescribed using heart rate during baseline fitness assessment. Cognitive training was administered using BrainHQ, an adaptive multidomain online platform. Pre- and post-intervention assessments included a maximal cardiorespiratory fitness test, a cognitive battery, and a cognitive and physical dual-task. A mid-intervention assessment included the fitness assessment and cognitive battery only. Throughout the intervention subjective workload was recorded alongside dropout and attendance, as measures of tolerability. All participants randomised with baseline assessments were included in intention-to-treat analysis using linear mixed effects models. **Results:** Peak aerobic fitness and time to exhaustion increased across the intervention with no difference between groups. Compared to PA, mean reaction time for PACog and PA&Cog was faster on a sustained attention task during the mid-intervention (PACog: $\beta = -28.9$ ms, 95% CI, −54.9 to −3.9; PA&Cog: $\beta = -36.1$ ms, −60.7 to −11.6) and post-intervention assessments (PACog: $\beta = -21.3$ ms, −47.0 to −4.4; PA&Cog $\beta = -29.8$ ms, −54.3 to −5.3). Response inhibition and memory improved over time with no group × time interaction. Eight participants withdrew prior to completion (PA: 2 of 17, PACog: 1 of 15, PA&Cog: 5 of 18), with no reports of adverse effects. Subjective workload did not vary significantly across the intervention or between groups. **Conclusions:** The reduced time impost, similar subjective workloads, and higher adherence places concurrent training as superior to separate training for improving several cognitive and physical performance characteristics in young healthy adults. **Military Impact:** Improvements in key cognitive constructs relevant to warfighter performance can be achieved with a concurrent training intervention, without the time cost associated with training cognitive and physical fitness separately. Concurrent training therefore appears to be a promising approach for improving and sustaining warfighter cognitive and physical performance.

14:15 – 14:30: Effect of total sleep deprivation and ammonia inhalants on reaction time in military personnel

Jan Malecek [1], Dan Omcirk [2], Jan Padecky [2], Zdenka Bendova [2], Katerina Skalova [2], David Kolar [2], Lubomir Privetivy [1], Karel Sykora [1], Michal Vagner [1], James J Tufano [2]

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[2]Charles University, Czech Republic

Purpose: Sleep deprivation is common for soldiers during prolonged operations, which may decrease cognitive performance. In such cases, soldiers seek ergogenic aids to sustain their performance. However, commonly used supplements require longer periods before their effects become apparent. Thus, this study aims to investigate the immediate effects of ammonia inhalants (AI), a faster-acting ergogenic aid, on the cognitive performance of sleep-deprived soldiers. **Methods:** Eighteen male cadets (24.1 ± 3.0 y, 79.3 ± 8.3 kg, 181.5 ± 6.3 cm) completed simple reaction time (SRT) tests after 0 (0), 12 (−12), 24 (−24), and 36 (−36) hours of sleep deprivation and then after 8 hours of recovery sleep (+8). Participants conducted 50 trials of a visual stimulus SRT test with randomized interstimulus intervals, using a laptop keyboard to respond as quickly as possible. Four tests were completed in a counterbalanced order, either with or without AI (CON), with a 2 min rest between each test. Trials with incorrect SRT (150 ms or > 3000 ms) were excluded from statistical analysis. Data were analysed using a two-way repeated measures ANOVA (2 conditions: [AI, CON] × 5 times: [0, −12, −24, −36, +8]). The variance explained by each ANOVA model is reported in η^2, and effect sizes are reported as Cohen's d. **Results:** We observed a significant main effect of time ($p = 0.009$, $\eta^2 = 0.19$) in SRT, where −12 was significantly slower compared to −24 (mean difference = 26.74 ms, $p = 0.002$, $d = 1.05$) and +8 (mean difference = 18.04 ms, $p = 0.007$, $d = 0.70$). There was also a significant main effect of condition ($p = 0.007$, $\eta^2 = 0.014$), demonstrating that AI reduced SRT (mean difference = 4.85 ms, $p = 0.007$, $d = 0.19$). We observed no significant condition × time interaction ($p = 0.500$, $\eta^2 = 0.006$). For a number of incorrect trials, although there was no significant main effect of time ($p = 0.250$, $\eta^2 = 0.051$), a significant main effect of condition ($p = 0.018$, $\eta^2 = 0.028$) demonstrating that AI reduced the number of incorrect trials (mean difference = 0.267, $p = 0.018$, $d = 0.267$). There was no significant condition × time interaction ($p = 0.112$, $\eta^2 = 0.026$). **Conclusions:** Although utilization of AI resulted in a 1.6% faster SRT regardless of sleep deprivation, there was no significant improvement in SRT observed in sleep-deprived soldiers. It is important to note that sleep deprivation can cause non-linear cognitive impairments, with the most considerable impact observed in the morning hours (3.2 - 9.3%). **Military Impact:** Regardless of sleep deprivation, AI may improve soldiers' SRT without increasing errors, potentially benefiting military contexts where SRT is critical. Although the observed difference was small, milliseconds matter in high-stakes scenarios, suggesting potential applications for AI in specific military situations.

14:30 -14:45: Salivary biomarkers in fighter pilots during a four-day military flying exercise

Otto Kinnunen [1], Tuomas Honkanen [2], Heikki Kyröläinen [3]

[1]Finnish Air Force, Finland
[2]Finnish Defence Forces, Finland
[3]University of Jyväskylä, Finland

Purpose: Individual flights and continuous operation can affect fighter pilots' performance level. For successful operation, it is crucial to identify pending degradation of one's performance. The purpose of the present study was to investigate potential signs of such degradation by analysing salivary biomarkers. **Methods:** Study population consisted of 25 volunteer Finnish Air Force fighter pilots who participated in a 4-day military flying exercise. The following salivary measures were collected daily at 1100 h, 1400 h, 1800 h, and 2200 h: α-amylase (AMYL), cortisol (COR), immunoglobulin A (IgA), dehydroepiandrosterone sulfate (DHEA-S), and testosterone (TES). After each flight, pilots reported how physically and mentally challenging they felt the sortie, and also gave themselves a flight grade. They also reported subjective feeling of weariness in the evenings. Control levels for each participant were determined by the same measurements in a light office week prior to the exercise. Linear mixed model analysis assessed: 1) the changes in biomarker concentrations during the exercise compared with control, and 2) relations of biomarker concentrations with subjective feeling of weariness and flight intensity, strenuousness, and performance. **Results:** During the exercise week, AMYL

($p = 0.321$), COR ($p = 0.123$), and TES ($p = 0.944$) concentrations were 3-5% higher, while IgA ($p = 0.239$), DHEA-S ($p = 0.137$) and TES / COR ($p = 0.269$) were 1-6% lower compared with the control. The number of sorties per day had a statistically significant positive relation ($F = 4.758$, $p = 0.03$) with COR, and negative relation with DHEA-S ($F = 7.459$, $p = 0.007$) and TES / COR ($F = 5.657$, $p = 0.018$). AMYL had a positive relation with cognitive strenuousness ($F = 4.812$, $p = 0.029$) and physical strenuousness ($F = 4.038$, $p = 0.045$) of the day's sorties. COR had positive relation with the cognitive strenuousness of the day's sorties ($F = 4.706$, $p = 0.005$). No statistically significant relations were found between the concentrations of the analysed biomarkers and the feeling of either mental or physical weariness in the evening. TES was the only biomarker to have statistically significant relation with flight grade ($F = 4.478$, $p = 0.035$). **Conclusions:** Stress related biomarkers AMYL and COR were slightly elevated, while another stress indicator TES / COR decreased during a short military flying exercise. Flight intensity and strenuousness seemed to have relation with salivary biomarkers of stress, but there were not any consistent relations between stress biomarkers and flight performance. This study gave hints that continuous operation accumulates physiological stress that can be observed with salivary biomarkers. **Military Impact:** Fighter pilots are operationally a vital military resource. It is, therefore, important to understand the physiological loading of their flight duties, to optimise their flight performance.

Oral Communication 4: Environmental Stressors, Exposures, and Injuries

Tuesday 12th September, 13:15 to 14:45

Room 3

Chair: *Jason Lee, National University of Singapore, Singapore*

13:15 – 13:30: Secure the future soldier's readiness through the brain-body connection using a neuroscience-informed approach

Charles Verdonk [1], Marion Trousselard [1], Mounir Chennaoui [1]

[1]French Armed Forces Biomedical Research Institute, France

Purpose: The French Armed Forces have reiterated the central role of the human combatant in the future of military operations. Despite ongoing efforts, the neurobiological mechanisms underlying impact of military stressors on the human combatant system are not thoroughly understood. In the light of recent advances in neuroscience research highlighting the brain-body connection as a key determinant of health and optimal cognitive functioning, we recently initiated several projects to examine how neuroscience-informed description of the brain-body connection may help to improve the soldier's adaptation to increasing cognitive and physical demands associated with military operations. **Methods:** We operationalise neuroscientific research on the brain-body connection through (1) the examination of how the quality of brain-body connection, which shows large interindividual variability, influences the soldier's readiness, and how it can be improved through body-centred training; (2) the predictive modelling of military-specific medical events from multilevel measures of body awareness, which refers to the neurophysiological processes by which the brain integrates the physiological state of the body (interoception) and its spatial relationship to the external environment (proprioception), and; (3) the assessment of the impact that changes in body signals, which can be elicited by a large collection of military stressors, have on cognition. **Results:** Our empirical findings showed that posture analysis, using posturography and machine learning models, predicts the individual risk of fall-related traumatic injury during Special Forces selection course with 70% accuracy (Study 1). Furthermore, we found that the significant reduction in self-reported interoception characterises individuals with a history of exertional heatstroke compared with age- and sex-matched healthy controls in military population (Study 2). Finally, using a centrifuge-based design to disrupt vestibular signal in healthy volunteers, we observed that the alteration of vestibular signal affects performance in inhibition (increased variability of the inhibition latencies) and decision-making (inadequate acceleration of the decision-making process) tasks (Study 3). On the basis of this evidence, our ongoing studies are now investigating how the brain-heart connection (i.e., cardiac interoception) may influence the interindividual variability of biofeedback learning outcomes (Study 4) and of thermophysiological response to heat stress (Study 5). We also assess the effectiveness of a body-centred intervention in reducing the risk of fall-related injuries during Special Forces selection courses (Study 6). **Conclusions:** Neurophysiological underpinnings of the brain-body connection may inform novel preventive strategies to improve the human combatant system. **Military Impact:** Transfer of research on the brain-body connection to military training contributes to improving soldiers' health and readiness.

13:30 – 13:45: Negative effect of sleep restriction on heat tolerance to even mild hyperthermia induced by passive exposure

Pierre-Emmanuel Tardo-Dino [1], Aurélien Germain [2], Vincent Beauchamps [1], Caroline Dussault [1], Keyne Charlot [1], Fabien Sauvet [1], Alexandra Malgoyre [1], Cyprien Bourrilhon [1]

[1]Institut de Recherche Biomédicale des Armées Brétigny, France
[2]Université d'Evry-Val d'Essonne, France

Purpose: Militaries, that regularly serve around the globe, are often exposed to hot climates. When on operations, they also undergo sleep restriction, which may decrease individual heat tolerance to acute heat stress. The impact of sleep restriction or deprivation on thermoregulation remains poorly documented. We hypothesised that even minor sleep restriction alters tolerance to acute heat exposure. We proposed to assess the effect of sleep restriction on heat tolerance to passive exposure, in particular through endothelial function, which has been shown to be altered by sleep debt. **Methods:** 13 healthy men (military and / or sportsmen) were examined in a randomised cross-over design, after getting a normal night of sleep (NN) (> 6 h) and sleep restriction (SR) (3 h). In both conditions, participants were exposed in a climatic chamber to passive-induced hyperthermia (core temperature over 38°C or +1°C) by uncompensable stress (45°C; 70% relative humidity; wind: 1.9 m·s-1, 90 min) then compensable conditions (42°C; 50% relative humidity; wind: 1.6 m·s-1, 60 min) to get a plateau of hyperthermia. Core and skin temperature (Tcore and Tsk), heart rate (HR), blood pressure, and cutaneous vascular conductance (CVC) were monitored. **Results:** During heat exposure after sleep restriction, passive heating induced higher elevation of both Tcore (heat effect p = 0.001; interaction of sleep restriction, p= 0.01) and HR (heat effect, p = 0.001; interaction of sleep restriction, p = 0.01). This alteration of thermoregulatory response was associated with lower elevation of CVC after sleep restriction (heat effect, p = 0.001; interaction of sleep restriction, p = 0.001). These effects were observed while no dehydration was induced by heat conditioning. **Conclusions:** These results showed an alteration in the ability to thermoregulate by sleep restriction. This higher core temperature was associated with cardiovascular stress. In addition, during exposure to heat, we observed a decrease in cutaneous vascular conductance. The higher heat strain, possibly induced by sleep restriction, may have been as a result of endothelial function. These first results highlight, for young men with putative healthy endothelium function, a potential mechanism of thermoregulation strain, even during mild hyperthermia. **Military Impact:** Countermeasures like endurance training or strategies to mitigate sleep disorders should be promoted to preserve, or even improve, heat tolerance on arrival in a hot climate.

13:45 – 14:00: Effectiveness of a short-term isothermal heat acclimation protocol in a military population

Koen Levels [1], Marijne de Weerd [1], Floris Paalman [1], Sam Ballak [2], Marc Duineveld [2], Lisa Klous [2]

[1]Royal Netherlands Army, The Netherlands
[2]Netherlands Organization for Applied Scientific Research (TNO), The Netherlands

Purpose: Soldiers often have to operate in hot environments. To reduce the risk of exertional heat illness and improve operational quality, heat acclimatisation / acclimation is essential. For complete thermoregulatory adaptations, 10 to 14 days are required during which a daily 60 to 90 min increase in core body temperature to 38.0 to 38.5°C is needed. For military operations, full heat acclimatisation is often hard to achieve as time and resources are limited. Therefore, the goal of this study was to investigate to what extent a five-day heat acclimation protocol can elicit thermoregulatory adaptations in a military population. **Methods:** 21 military personnel (four women, 17 men) visited a climatic chamber on five consecutive days. Each day they performed 90 min of exercise in 35.1 ± 0.4°C and 52 ± 2% relative humidity. The first 30 minutes consisted of cycling at 1.5 Watts per kilogram body weight. The goal of this period was to increase core temperature to 38.0 to 38.5°C. The following 60 minutes, cycling intensity was continually adjusted to maintain this temperature. Heart rate, gastrointestinal temperature, and mean skin temperature were measured every 1 min. The rating of perceived exertion, thermal sensation and thermal discomfort were measured every 10 min. Data of the first standardised 30 min was used for analyses. **Results:** From day 1 to 5, average heart rate decreased from 145 ± 14 b·min-1 to 137 ± 12 b·min-1 ($F = 6.64$, $p < 0.01$). The increase in gastrointestinal temperature and mean skin temperature during the first 30 min of cycling remained similar from day 1 to day 5: 1.3 ± 0.3°C to 1.1 ± 0.3°C ($F = 2.24$, $p = 0.11$), and 2.1 ± 0.7°C to 2.5 ± 0.8 ($F = 0.97$, $p = 0.10$), respectively. The average rating of perceived exertion decreased from 3.9 ± 1.3 to 2.9 ± 0.9 ($\chi^2(4) = 30.41$, $p < 0.01$), and thermal sensation from 1.9 ± 0.7 to 1.5 ± 0.7 ($\chi^2(4) = 14.44$, $p < 0.01$). Thermal discomfort remained unchanged from day 1 (1.4 ± 0.7) to day 5 (1.2 ± 0.7) ($\chi^2(4) = 9.38$, $p = 0.23$). **Conclusions:** Partial heat acclimation was achieved during the five-day isothermal protocol; the changes in perceptual scores were substantial. Compared with literature data it is estimated that the overall effectiveness of this short-term protocol is roughly 60% of complete acclimatisation, although this estimation differs greatly per variable. **Military Impact:** A relatively large portion of heat acclimation effects can be achieved within five days of consecutive exercise in the heat. Although heat acclimatisation is incomplete, a short-term heat acclimation protocol can reduce the risk of exertional heat illness and improve operational quality. However, special attention for the occurrence of heat illness is still needed in the risk assessment of operations in the heat.

14:00 – 14:15: Urinary metabolites measured at sea level predict altitudeinduced acute mountain sickness outcome

Camilla Mauzy [1], Isaie Sibomana [1,2], Nicholas Reo [3], J Philip Karl [4], Claire Berryman [4], Andrew Young [4]

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Purpose: To examine metabolic changes related to acute mountain sickness (AMS) susceptibility, we analysed urine samples from participants at sea level and at high altitude.

Methods: Following a 21-d sea level (SL) testing phase at the USARIEM (Natick, MA, USA; 50 m), 17 healthy men were transported to 4300 m where they resided for 21 d. AMS symptoms were measured at sea level and three times daily during the first 72 h at altitude using AMS-cerebral factor scores derived from the Environmental Symptoms Questionnaire-Short Form. Proton NMR analyses were conducted on the urine samples to assess metabolite changes. Spectra data were subjected to multivariate exploratory analyses such as principal component analyses (PCA) and orthogonal projection into latent structures discriminant analysis (OPLS-DA). **Results:** PCA clearly separated the urinary spectral profiles collected at SL from participants that later, at altitude, experienced moderate-to-severe AMS (AMS-C; mean ± SD 2.28 ± 0.55) compared with those that displayed no or mild AMS (NoAMS; 0.78 ± 0.44). These data were further subjected to OPLS-DA to determine the spectral features that discriminate AMS susceptible and AMS resistant groups. Normalised NMR spectra were used to quantify specific metabolite resonances determined by OPLS-DA to be important for group classification. Quantification of these metabolite resonances was accomplished using an interactive spectral deconvolution algorithm in MATLAB. We identified a set of eight metabolites, which primarily drove the segregation between urinary metabolite profiles for AMS and NoAMS individuals at sea level. They included creatine, 4-hydroxyphenylpyruvate, acetylcarnitine, 3-methylhistidine, taurine, N-methylhistidine, hypoxanthine, and 1-methylnicotinamide. **Conclusions:** Several of these metabolites, especially creatine, 3-methylhistidine, and acetylcarnitine are synthesised and / or metabolised in the muscle and have been previously shown to impact brain activities. These observations suggest that these metabolites could be indicative of a pre-existing physiological status reflecting a predisposition to AMS and could potentially be used to predict—at sea level before ascending to high altitude—which participants would be at greatest risk for experiencing AMS at high altitude. **Military Impact:** AMS predictive biomarkers will provide a fast, non-invasive method to identify military personnel who, due to mission timelines and battle rhythm, may not have adequate time for altitude and who, at attitude, will experience significant performance and mission degradation. Disclaimer: The views expressed are those of the authors and do not reflect the official guidance or position of the United States Government, the Department of Defense, the United States Air Force, the United States Space Force, or the United States Army. Distribution A. Approved for public release, distribution unlimited. PA Case Number: AFRL-2023-0432, Case Reviewer Number: 2023-0062; cleared 16 Feb 2023

14:15 – 14:30: Protective effect of a high heat capacity mattress on sleep during heat exposure

Fabien Sauvet [1], Florane Pasquier [2] ; Jonathan Monin [3], Pascal Van Beers [1], Pierre-Emmanuel Tardo-Dino [1], Michael Quiquempoix [1], Mathias Guillard [1], Keyne Charlot [1], Mathieu Nedelec [2]

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[2]INSEP, France
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Purpose: Sleep is an essential part of physical and psychological recovery in military environments. However, sleep is strongly affected by heat exposure, through circadian thermoregulation dysfunction. Acute exposure to heat environments can disrupt sleep duration and quality. Recent publications demonstrated that high heat capacity mattress improve sleep duration and quality, particularly after physical exercise through lowering central temperature during the night. The aim of the present study was to assess the protective effect of a high heat capacity mattress (HHCM) on sleep duration and quality during night heat exposure compared with a control mattress (CM). **Methods:** Fifteen healthy young athletic participant (> 4 h·day1 physical activity), without sleep disorders were included. A randomised double-blind crossover design was used to evaluate the impact of HHCM compared with CM on sleep and temperature during heat night exposure condition (32°C) and a temperate night exposure condition (22°C). Participants slept four nights in laboratory conditions: two nights at 22°C (HHCM and CM), and two nights at 32°C (HHCM and CM). Relative humidity was 40 ± 5%. Participants time in bed was 9 h (22:00 to 07:00). In all conditions, sleep was recorded by polysomnography. Core body, skin, room, and mattress surface temperatures were continuously recorded. **Results:** Compared with the temperate night exposure, heat night exposure had a lower total sleep time (TST) (−60.8 ± 27.1 min, $p < 0.01$), rapid eye movement (REM) duration (−16.5 ± 5.2 min, $p = 0.03$), and sleep efficiency (−6.2 ± 2.1%, $p = 0.04$), and higher awakening after sleep onset (+16.3 ± 4.1 min, $p = 0.03$) and fragmentation. At 22°C we there was no beneficial effect of HHCM compared with CM on sleep. However, higher TST (+21.4 ± 16.1 min, $p < 0.05$), sleep efficiency (+ 5.0 ± 3.7 %, $p = 0.04$), REM duration (+ 13.2 ± 5.1 %, $p = 0.04$), and lower awakening duration (− 11.1 ± 4.3 min, $p = 0.03$) were demonstrated with HHCM compared with CM in the 32°C condition. These effects were associated with lower skin (−0.22 ± 0.06°C, $p < 0.01$) and core body temperature (−0.21 ± 0.02°C, $p < 0.01$). **Conclusions:** Sleeping on a HHCM during heat exposure has a protective effect on several sleep parameters, and limits increases in body temperature, compared with CM in a healthy population. HHCM could be used as a countermeasure for promoting sleep in athletes or soldiers, during training or missions in a hot environment. **Military Impact:** Acute heat exposure decreases sleep duration and quality. A HHCM could mitigate the negative effects of heat exposure on sleep.

Posters 1: Data Analytics and Predictive Modelling

Tuesday 12th September, 13:15 to 14:45

Board 1: Military occupational injury risk analysis using machine learning decision trees

Joseph R Pierce [1], Qi Mi [2], Tyson Grier [1], Anna Schuh-Renner [1], Michelle Canham-Chervak [1], Bruce H Jones [1], Mita Lovalekar [2], Bradley C Nindl [2]

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Purpose: Injuries are the leading cause of medical encounters among U.S. Army soldiers. A recent machine learning decision tree analysis indicated only previous injuries were predictors of future injuries among male soldiers. There may, however, be different injury risk factors for soldiers in different military occupational specialties (MOSs). This study utilised decision tree algorithms to potentially identify different injury risk factors among male soldiers from multiple MOSs. **Methods:** Enlisted male soldiers from an Army light infantry brigade of Armor (n = 426), Infantry (n = 411), and Mechanical Maintenance (n = 388) MOSs completed surveys capturing demographics, anthropometrics, previous injury occurrence within 6 and 12 months, and health-related behaviours (e.g., tobacco use, physical training). Soldiers also completed field-expedient fitness tests (functional movement screen, Army Physical Fitness Test (APFT), agility tests, etc.). Machine learning analysis was conducted using Classification and Regression Trees (CART) algorithms via R 3.6.3, rpart (v 4.1.15) package. Based on 10fold cross-validation, the one standard error rule (1-SE rule) was used to find the optimal number of tree splits. Prospective injuries (6- or 12-month follow-up) were identified in medical records by International Classification of Diseases Ninth Revision (ICD-9) codes and included acute and overuse musculoskeletal (sprains, bone stress injuries, etc.) and non-musculoskeletal (blisters, heat injuries, etc.) injuries. Sensitivity, specificity, and F1 score (harmonic mean of precision and recall) were used to assess model performance. **Results:** MOS-specific injury incidence at 6- and 12-months follow-up, respectively, was: Armor, 37.8% and 55.4%; Infantry, 37.5% and 56.4%; Mechanical Maintenance, 48.2% and 67.0%. CART analysis by MOS yielded different decision tree models; however, the models shared similar F1 values (range = 0.620 - 0.642). For most models, one split was optimal, with an injury 6 months prior predicting future injuries at 6- or 12-months follow-up. Only the Armor model (sensitivity = 0.658; specificity = 0.717; F1 value = 0.620) contained an additional split (APFT 2-mile run time ≥13 min) for soldiers injured 6 months prior. No other health behaviours or fitness factors predicted future injury within 6- or 12-months among men in these MOSs. **Conclusions:** Despite using MOS-specific injury prediction models, the most important factor predicting a future injury through 12-months follow-up was an injury 6 months prior to the investigation. Only one additional measure (APFT 2-mile run ≥13 min) was a predictor of future injury in previously injured Armor soldiers. **Military Impact:** The current machine learning CART analysis provides updated information for MOS-specific injury predictions. Injury type and location may influence military decision tree models and requires further investigation.

Board 2: The probability of becoming an Operator given specific Test resultS P(O|TS): design and preliminary acceptance results of the physical testing part of a nationwide study

Alain Doessegger [1], Martin Flueck [2], Thomas Gsponer [3], Thomas Wyss [1], Gilgen-Ammann Rahel [1], Christian Protte [1], Oliver Faude [4]

[1]Swiss Federal Institute of Sport Magglingen, Switzerland
[2]University of Fribourg, Switzerland
[3]Stadl Partners GmbH, Switzerland
[4]University of Basel, Switzerland

Purpose: Job dropout due to health problems are common in Special Operation Forces (SOF). Selection of training responders aims to ensure operational fitness—the readiness to respond at any time—and to protect against overuse and injuries. A nationwide study aimed to identify potentially capable operators and provide individually tailored training recommendations based on genotypes and actual performance parameters to the tactical athlete community. Here we present the study design and acceptance results. **Methods:** Physical fitness data, gene polymorphisms, and training habits were collected from candidates applying for SOF in a pre-selection process and from current operators using REDCap as an electronic data capture tool. Fitness parameters including impulse (“power”), maximal muscular strength, strength endurance, short-, mid-, and long-term endurance, blood markers, executive function, and psychological traits were measured. Fitness tests are strongly related to SOF specific key job performance indicators (KPI). Polymerase chain reaction analysis (PCR) was used to assess eight gene polymorphisms, as well as gene methylations of stress markers. Training habits and psychological traits were collected by questionnaire. Based on these data, individually tailored training recommendations were provided to the SOF. Data from current operators are used as benchmark to compare with candidate’s performance levels. Acceptance of the operationalisation test parameters from KPI were validated by online questionnaire using Likert scale acceptance with a sample of active SOF operators and Police officers. **Results:** Testing procedures, PCR analyses, and anonymisation procedure of SOF operators are established. Fitness tests are covering the main critical success factors and KPI of SOF. Acceptance rate of the physical fitness tests range from 65% (standing long jump) to 100% (reaction tests). **Conclusions:** Operators highly agree with the tests covering their job requirements that could identify potentially capable operators. Genotypes and training habits together may explain the phenotypes or fitness profile of tactical athletes. Individualised training recommendations seem to be welcome among tactical athletes. Physical performance tests will be repeated after a training phase to identify training responders. Selection or dropout will be observed prospectively. The probability of dropout or musculoskeletal injury will be calculated using a Bayesian approach. A predictive model for the dropout will be calculated, taking into consideration the effect of training on the test results. The interdisciplinary study design allows to prospectively study training response and dropout rate. **Military Impact:** SOF candidates may benefit from individualised training recommendations, while the Armed Forces may benefit from evidence-based selection tests and operationally fit personnel.

Board 3: Upper respiratory tract infection detection with wearable technology

Christina D Young [1], Charlotte V Coombs [1], Rebecca L Knight [1], Julie P Greeves [1], Thomas J O'Leary [1]

[1]Army Health and Performance Research, UK,

Purpose: Upper respiratory tract infections—including COVID-19—can be easily transmitted and outbreaks can disrupt military training and affect deployability. Infectiousness can peak before symptoms present, and early detection methods may facilitate decision-making to reduce transmission. British Army recruits, training staff, and healthcare workers may be at an increased risk of upper respiratory tract infections due to working and living in proximity with others. This study aimed to quantify the incidence of upper respiratory tract infections and COVID-19 in service personnel, and to test the efficacy of wearable devices for the early detection of upper respiratory tract infections and COVID-19. **Methods:** 172 British Army Personnel (mean ± SD, age 25.3 ± 7.4 y, height 1.77 ± 0.13 m, body mass 80.3 ± 14.7 kg) volunteered to participate. For thirty consecutive days, participants self-administered a throat and nose swab for detection of COVID-19, reported daily symptoms of COVID-19, completed the Jackson common-cold questionnaire for the detection of upper respiratory tract infections, and wore a smartwatch during sleep. A daily risk score (high or low) of upper respiratory tract infections was determined from the wearable using a commercially available algorithm. Diagnostic performance of the risk score was calculated using sensitivity, specificity, and positive and negative predictive values (PPV and NPV). **Results:** 2,653 throat and nasal swabs were analysed. COVID-19 was not detected in any participant, but the incidence of COVID-19-specific symptoms was 1 per 131 days. The incidence of any upper respiratory tract infection symptoms (Jackson score ≥ 6) was 1 per 73 days. The performance of the wearable algorithm for detecting any upper respiratory tract infection on the day symptoms occurred (sensitivity = 22%, specificity = 84%, PPV = 6% , NPV = 96%), and 1 day (sensitivity = 20%, specificity = 85%, PPV = 6%, NPV = 95%) and 2 days (sensitivity = 17%, specificity = 85%, PPV = 6%, NPV = 95%) before symptoms developed was moderate. **Conclusions:** The wearable device and algorithm in this study was not sensitive for detecting COVID-19 or upper respiratory tract infections in a high-risk military population. The high number of high-risk warnings when no infection or symptoms were present was likely due to other physiological disturbances in military training or employment. **Military Impact:** There is currently insufficient evidence to support the use of wearable devices for identifying upper respiratory tract infections in a military population. Symptom reporting should be prioritised, but studies should examine the symptomology of illness in a military population to identify sensitive detection methods.

Board 4: Development and implementation of an onboard physical load monitoring and feedback system for high-speed craft operators

Lotte Linssen [1], Kaj Gijsbertse [1], Jan U van Baardewijk [1], Thijs Hasselaar [2], Pepijn de Jong [2], Joost de Haan [3], Pierre Valk [1]

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Purpose: Repeated high-impact shocks experienced by marine personnel operating high-speed craft can cause significant physical discomfort, and in some cases, may result in spinal injuries. An adequate monitoring and feedback system can inform operators about their actual and cumulative physical load and therefore mitigate injury risk. However, existing onboard monitoring systems do not capture human body-related measures. Moreover, current injury risk prediction models lack marine-specific data, as they are primarily based on data from automotive crash and lifeboat drop tests. In response, our research has focused upon on the development of instrumentation technology that measured acceleration forces on the boat, seat, and human body as an integral system. Additionally, we aimed to evaluate the relationship between cumulative physical load and injury risk through a longitudinal trial, with the aim of improving current injury risk models. **Methods:** The following measurement set-up was used: three accelerometers were placed at the front, back, and middle of the craft, one accelerometer placed on each seat, and two accelerometers placed on the spine (thoracic-1 and lumbar-1). Discomfort events during the ride could be indicated via discomfort buttons, and physical complaints before and after the ride was collected with a pre- and post-ride questionnaire. Laboratory and onsite tests were performed to assure for reliable data collection before trial start. **Results:** This integral approach resulted in an on-board objective and subjective load monitoring and feedback system. One crew (n = 10) is currently participating in a longitudinal study (8 to 12 months), in which they use the monitor technology during their training and operations. This provides a database to determine the relation between physical load and injury risk. **Conclusions:** There is currently insufficient evidence to determine the relationship between physical load and injury risk. However, this promising technology development can be used as a blueprint for managing injury risk while operating high speed craft. Furthermore, it will add to the specification guidelines for future high-speed craft that go even faster, where controlling and mitigating the injury risk is key. **Military Impact:** Providing feedback to operators about their perceived physical load and injury risk allows for informed decisions about their strategies and training intensity. Additionally, this system allows for the evaluation of new seats or craft that intend to reduce the physical load and enhance safety of operators.

Board 5: New data analytics approach to marksmanship training

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Purpose: XCALIBR is a new digital marksmanship capability designed to establish a high fidelity individual and collective record of marksmanship performance. Two particular features stand out in this approach: the use of the MantisX commercial off-the-shelf device, measuring weapon deflection in and around the moment of shot release, and; the use of digitally paired Location of Miss and Hit Targets in standard and static Live Fire Marksmanship Training

(LFMT), and in dynamic Live Fire Tactical Training (LFTT), an area almost entirely unmeasured hitherto. The purpose of the capability and the study was to investigate the impact of putting rich performance and diagnostic data not only into the hands of coaches, but also directly into the hands of individual users. **Methods:** The XCALIBR Infantry Training Centre (ITC) project consisted of nine work packages conducted over a 12-month period to progressively develop and deliver XCALIBR to support three recruit platoons on successive ITC intakes. A project design was developed to exploit historical data on Annual Combat Marksmanship Tests (ACMT) at ITC, and some sampling of control groups during the LFTT component. An enduring design limitation throughout was the need to operate unobtrusively entirely within the existing ITC program, which meant there was limited control over LFTT conduct variables. A wide range of data science methods were used to analyse, in depth, a large and rich dataset. The generative pass rate for two groups were assessed using the Bayesian Monte Carlo Python library (PyMC). This allowed a comparison of the distributions of possible pass rates that could have generated the observed pass rates in the XCALIBR and control groups. In another study we look at the activity before each shot and the impact it had on performance; specifically, we focused on the movement recorded by GPS in the two minutes preceding the shot, where the GPS position is given every 5 s. **Results:** High density intervals did not overlap in this analysis indicating that the underlying pass rate for the XCALIBR group is significantly higher than for the control group. The hit percentage plotting indicated that the hit percentage is higher for shots where there was less than 20 metres of movement preceding the shot. **Conclusions:** Without any change to the existing ITC training program, the first-time pass rate of the culminating ACMT was approximately doubled. Despite significant experimental variability, significant improvements were also detected in the most demanding LFTT component. **Military Impact:** Changes could be made on the marksmanship program format driven by new data sources, with significantly greater clarity and insight available on performance and diagnostic analytics. This in turn offers the prospect of higher standards inside the same program envelope and/or the existing standard met in a more compressed program.

Board 6: Ergonomic fit evaluation of personal protective equipment using 3D scan technology

Laura Ahsmann [1], Marc Duineveld [1], Marielle Besselink-Weghorst [1]

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Purpose: This study examines the potential use of 3D intersection analysis of military protective equipment on ergonomic fit assessment. This type of assessment could be used to evaluate potential problems of fit of both rigid and non-rigid materials in relation to personal characteristics and specific clothing and equipment configurations. **Methods:** An ergonomic fit evaluation methodology is proposed using 3D scanning technology in combination with post-processing analyses in 3D manipulation software (Artec Studio and Autodesk Meshmixer). 3D scans are made of (part of) the human body, and the interface geometry of the protective equipment. A combined configuration scan is used for alignment processing steps. In post-processing steps, a Boolean difference analysis is executed to generate the intersecting

geometry between the scans of the body and protective equipment. To validate the relevance of 3D scan data to assess discomfort, subjective data on locally perceived discomfort (Borg-scale) is collected and compared to the intersection data. The methodology was assessed in a fit evaluation of helmets in combination with over-ear hearing protection (n = 29). The 3D local spatial intersection values (in mm) between 3D scans of the head and the helmet were compared to the subjective discomfort rating at the same location on the head. **Results:** Results show that higher rates of discomfort can be backed by the 3D spatial intersection data. The assessment required the notion of material properties and the shifting of wearables caused by contact. Besides intersection values, the 3D fit evaluation methodology also provides insights on differences in body type (in this case the head shape). **Conclusions:** 3D fit evaluation using intersection analysis shows promising results as assessed in a helmet fit evaluation related to discomfort, as it reveals accurate spatial contact area and indentation of rigid and non-rigid materials between the body and the worn equipment. An accurate prediction was made of potential problems related to fit and discomfort, especially when accounting for differences in material properties and soft-tissue artefacts. **Military Impact:** Every user is different and one size fits nobody. This methodology can be used to accurately evaluate or predict the fit of personal protective equipment or clothing of a selected population. It could also be used to adjust, design, and develop ergonomically appropriate or even custom-made equipment and clothing. With a demand for more and more body-worn equipment, potential future fit-related issues could be evaluated.

Board 7: Development of early warning systems: how to assess one's physiological individual baseline information

Theresa Schweizer [1], Petra Ribiczey-Rüegger [1], Rahel Gilgen-Ammann [1]

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Purpose: Heat and fatigue-related health issues can be reduced by monitoring the soldier's individual health state and creating an early warning system (i.e., digital twin). Individual baseline, comprising heart rate (HR), core body temperature (CBT), skin temperature (Tskin) and HR variability (HRV), is crucial to provide a reference point to identify any deviations from an individual's normal or expected range. Most studies use short-term (3 to 5 min) or long-term (24 h) baseline measurements (BMs) to establish individual baselines. This pilot study investigated the variability and equivalence of individual baseline values in short and long BMs obtained in a military field environment. **Methods:** Twenty-two male recruits (mean age 21.1 y) of the Swiss Armed Forces completed three short, standardised BMs (3 × 3 min lying, standing, walking) followed by 21 h long free-living BMs (day and night), on two non-consecutive days (military routine). Participants wore four devices: Polar Verity Sense for HR, Polar H10 for RR intervals, CALERAresearch for CBT and Tskin. Resting HR was calculated from lying. Root mean square of successive differences (RMSSD) was derived from rr-intervals. Intra-BMs variability was assessed using coefficient of variation (CV). Differences and equivalence of means between corresponding BMs were assessed using Wilcoxon signed-rank test and two one-sided tests. Data quality was analysed, and recruits with incomplete data or artefacts were

removed. **Results:** Eight recruits were included in the analysis after data quality check. For short BMs, CVs were 1% for CBT and Tskin. For HR, CVs were 10% for lying and walking and 4 - 18% for standing. For long BMs, CVs were 4% for CBT and Tskin. For HR, CVs were 13 - 22% for day and 6 - 22% for night. Comparing corresponding BMs, significant differences were found in CBT (night), Tskin (day), and HR (walking) ($p < 0.05$). No statistically significant differences were found between the other BMs for CBT, Tskin, HR, resting HR, and RMSSD ($p > 0.05$). However, two one-sided tests showed no significant equivalence ($p > 0.05$). **Conclusions:** HR showed high intra-BM variability, even in short, standardised BMs. Additionally, night measurements showed differences in individual baseline values. Despite no significant difference between both occasions in most parameters, there is insufficient evidence to support the equivalence of these individual baseline values. **Military Impact:** To develop accurate early warning systems in military settings, individual baselines should be monitored over a longer period, for both short standardised and long free-living BMs. It is recommended to control all possible influencing factors as well as monitor individual baseline information not only on one single occasion.

Board 8: Finite element modelling framework for evaluating the effectiveness of protective plates in minimising tissue damage resulting from a non-penetrating ballistic impact

Yoram Epstein [1], Maayan Lustig [1], Amit Gefen [1]

[1]Tel Aviv University, Israel,

Purpose: Injuries in the torso (chest, abdomen, and spine) are relatively common in a combat environment and constitute ~30% of all injuries. A penetrative insult results with mechanical damage and internal organ disruption that may be debilitating and might even be fatal. To minimise injury, protective armour is part of the soldier's equipment. However, even a non-penetrative blunt trauma might cause severe tissue damage that can be fatal. The latter is due blocking of the ballistic threat by an armour, which is accompanied by rapid and immediate deformations of the armour that translates to mechanical energy absorbed in the tissues behind the armour and injury. This process is referred to as Behind Armor Blunt Trauma (BABT). No reproducible realistic measure exists to quantitative or even qualitative assess BABT. The objective of this study was to develop a novel, anatomically accurate, finite element modelling framework as a decision-making tool to evaluate and rate the biomechanical efficacy of protective plates in protecting the torso from battlefield-acquired non-penetrating impacts. **Methods:** The finite element simulations resemble a non-penetrating ballistic impact of a 5.56 mm bullet with different types of protective plate. A three-dimensional model of the torso and its inner organs was reconstructed, and two Kevlar-29 ballistic protective plates were modelled, representing generic designs of threat-level III and IV plates (according to NIJ Standard–0101.06). The performance of each plate was quantitatively evaluated and objectively compared based on biomechanical metrics that develop in internal tissues of vital organs immediately after the impact, specifically, the pattern of strains and stresses in the tissues. **Results:** The results indicated that plate level-IV induces greater tissue strains and stresses post the ballistic impact than plate level-III. The area under volumetric tissue exposure histograms of strains and stresses for the skin and adipose tissues, were 16.6 - 19.2% and 17.3 - 20.3% greater in the case of plate level-IV,

for strains and stresses, respectively. **Conclusions:** Due to the larger and heavier structure of plate level-IV, higher strains and stresses were observed. Our modelling system provides a versatile, powerful testing framework for both industry and clients of protective plates, at the prototype design phase, or for quantitative standardised evaluations of candidate products in purchasing decisions and bids. **Military Impact:** Using this innovative approach, it is possible to considerably shorten development and procurement processes of protective gear and to carry out advanced experiments after initial evaluation using computational models.

Posters 1: Physical Performance

Tuesday 12th September, 13:15 to 14:45

Board 9: A smartphone application tests your physical performance: how accurately does the 4-minute all out run measure your endurance performance? A pilot study

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Purpose: The Swiss Armed Forces have released a sports app for tailor-made fitness training. The integrated training recommendation takes into account the current endurance capacity. This is done by means of a digital fitness self-test. The Cooper test (12-min run), which is widely used in the military setting, is too long for the digital self-test and it is difficult for untrained people to choose the right pace. This study aims to investigate whether a 4-min all out run is a valid method for assessing endurance performance. **Methods:** In this pilot study six students (one women, age 27.5 ± 6.7 y, height 1.75 ± 0.12 m, body mass 69.5 ± 5.6 kg) completed a 4-min self-paced all out outdoor run on a 300 m flat circular track. Average speed (v4MIN; km·h-1) was calculated. To determine the maximum oxygen uptake (VO2max) and the final speed (vEND; km·h-1), a graded protocol from initial 7.5 km·h-1 with 7% constant incline and a speed increase of 0.5 km·h-1 every 30 s to exhaustion on a treadmill (CPET mixing chamber; COSMED). Pearson correlations and linear regressions were calculated with the VO2max, vEND, and v4MIN values. **Results:** Participants achieved a mean v4MIN of 15.6 ± 2.5 km·h-1. The VO2max (mean 51.0 ± 8.7 ml·min-1·kg-1) and the v4MIN (model 1; r = 0.945; p = 0.004; 95% CI: 0.575 - 0.994) as well as the vEND (mean 13.8 ± 2.2 km·h-1) and the v4MIN (model 2; r = 0.968; p = 0.002; 95% CI: 0.731 - 0.997) were strongly correlated. The linear regression of model 1 had a corrected R2 of 0.867 (F = 33.676, p = 0.004), model 2 had a corrected R2 of 0.922 (F = 59.870, p = 0.002). **Conclusions:** The preliminary results of this pilot study showed that the 4-min all out run performance can accurately estimate both VO2max and vEND. Thus, this test has great potential and will be further investigated within a larger sample size. **Military Impact:** The Swiss Armed Forces offer their recruits and soldiers a digital solution for physical training before, during, and between military service. A digital fitness test that can be carried out independently, regardless of time and place, and without special equipment, supports the responsible sports coaches. The 4-min all out run is a promising solution to assess the endurance performance of military personnel and is an alternative to conventional laboratory and field tests.

Board 10: Soldier strength responses to prolonged load carriage during a 72-hour mission

Angela Boynton [1], Morgan Salazar [1], Maria Talarico [1], Jessica Schindler [2], Kevin O'Fallon [2], Seth Elkin-Frankston [2], Victoria G Bode [2]

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Purpose: While the cardiopulmonary and biomechanical responses to military load carriage have been studied extensively, changes in muscular strength associated with this physically demanding task are not well documented. The extent to which load carriage-related changes

might persist over the course of subsequent mission activities are additionally unknown. This study investigated the acute and sustained effects of prolonged load carriage on soldier strength capacities within the context of a 72-hour mission. **Methods:** One-hundred thirty-six male U.S. Army Infantry Soldiers completed loaded ruck marches at the beginning (INFIL) and end (EXFIL) of a 72-hour mission. Participants carried approximately 40 kg over a 13 km INFIL ruck march and approximately 33 kg over an 11.7 km or 7 km EXFIL ruck march. Isometric strength was assessed immediately before (PRE) and after (POST) each event. Maximum force was measured from three repetitions each of grip, pinch, hip flexion, knee extension, lumbar flexion, lumbar extension, biceps curl, upright row, deadlift, and calf raise tasks. Independent paired t-tests or Wilcoxon signed rank tests were performed between PRE and POST INFIL measures and between PRE INFIL and PRE EXFIL measures to identify acute and persistent effects, respectively. **Results:** Statistically significant decreases from PRE to POST INFIL were identified for grip (mean 95% CI, −0.7 [−3.9, 2.4] %, $p = 0.044$), hip flexion (−0.5 [−6.8, 5.8] %, $p = 0.029$), knee extension (−6.5 [−12.5, −0.6] %, $p < 0.001$), lumbar extension (−6.5 [−11.3, −1.7] %, $p < 0.001$), biceps curl (−3.8 [−6.8, −0.8] %, $p < 0.001$), deadlift (−11.2 [−14.7, −7.6] %, $p < 0.001$), and calf raise (−8.8 [−13.2, −4.4] %, $p < 0.001$). Pinch and lumbar extension did not significantly differ between PRE and POST INFIL. Between PRE INFIL and PRE EXFIL a statistically significant decrease was only observed for grip (−2.8 [−7.3, 1.6] %, $p < 0.001$). For all other measures, PRE EXFIL values either did not significantly differ from or were significantly increased from PRE INFIL values. **Conclusions:** Prolonged load carriage induces acute deficits in soldier hand, leg, and trunk strength, and reductions in grip strength can persist over a 72-hour mission. Future studies should evaluate relationships between near- and long-term impacts of identified strength deficits on individual task and overall mission performance and explore the potential for mitigation of load carriage effects through targeted physical training of the affected muscle groups. **Military Impact:** Reductions in individual soldier and collective squad strength following a strenuous ruck march can negatively affect readiness and performance. Operational effectiveness may be improved by anticipating and accounting for these effects during training and mission planning.

Board 11: Functional movement screen performance of US Army activeduty light infantry soldiers

Maria Talarico [1], Jennifer Sperlein [1], Angela Boynton [1], Kevin O'Fallon [2], Wade Elmore [2]

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Purpose: The Functional Movement Screen (FMS)™ is a tool designed to quantify movement quality and asymmetries in movement patterns with the potential to identify injury risk. Little information is available on functional movement characteristics of US light infantry soldiers. This study aimed to provide overall FMS™ performance of US Army infantry units and identify relationships between self-reported injury history and FMS™ performance. **Methods:** Three-hundred and ten US Army light infantry soldiers (4 females, 306 males) completed the FMS™ while rested and prior to physically demanding activities (e.g., maximal strength tests). FMS™

was completed by soldiers across six US Army Divisions at six installations. Soldiers self-reported injury history prior to testing. Injury history included any injuries in the soldier's lifetime and included: (1) activity during which the injury / injuries were sustained, (2) type of injury / injuries, and (3) location of injury / injuries. Total screen scores from FMS™ were calculated out of a possible 21 points and were reported descriptively. Multiple linear regression models were conducted to identify the influence of injury history on FMS™ total screen score and sub-scores while controlling for division and years of active duty. **Results:** Overall, soldiers with any injury history had a total screen score 0.78 points lower (14.5) than those with no injury history (15.2) ($p = 0.02$). Soldiers from the 82nd Airborne had a total screen score 1.6 points higher than that of 4th Infantry Division ($p = 0.02$). Soldiers with a history of a lower leg injury had a total screen score 1.94 points higher than those with no lower leg injury history ($p = 0.01$). Those with a sprained ankle history had a total screen score 1.00 points lower than those with no sprained ankle history ($p = 0.04$). **Conclusions:** Over 75% of light infantry soldiers reported a history of injury; of those with an injury history, lower body injuries were a significant contributor to functional movement performance. Consideration of injury history and other individual factors are warranted when evaluating soldier physical performance for optimal readiness and injury mitigation as these factors directly influence functional movement. **Military Impact:** Movement screening provides critical baseline operational readiness information that can expose the implications of immense physical stressors and injury sustainment. Attention to functional movement prior to duty and field operations can be used to better inform operational performance and may mitigate vulnerability.

Board 12: The physiological demands of helicopter winch rescue in water and over land

Ben Meadley [1], Ella Horton [1], Luke Perraton [1], Kelly-Ann Bowles [1], Joanne Caldwell [1]

[1]Monash University, Australia

Purpose: Personnel working in helicopter rescue teams perform demanding work in remote wilderness and open water. This study aimed to determine the physiological workload during critical helicopter search and rescue tasks. We sought to assess relative physiological demands and maximal acceptable work duration of helicopter rescues to inform physical employment standards for this population. **Methods:** To assess the physiological demands of winch rescue, 14 flight paramedics (12 men / two women, mean ± SD, age 44.3 ± 5.4 y, experience 7.1 ± 5.2 y) completed a peak oxygen consumption test on a treadmill, and land and water task simulations. The land simulation consisted of a 250 m walk at a gradient of 18% carrying 43.4 kg of equipment. The water simulation consisted of two repetitions of a 50 m open water swim, wearing water rescue equipment to retrieve a mannequin (mass) from a life raft, followed by a 25 m tow of the mannequin. During all simulations, expired gases were collected to determine oxygen uptake (VO2). Blood lactate, heart rate, and ratings of perceived exertion (RPE, 6-20) were recorded. Maximal acceptable work duration was calculated from expired air. Results**:** Land task simulation VO2 was 41.7 ± 4.5 mL·kg-1·min-1, equalling 86 ± 11 % of VO2peak. Land task duration was 7.0 ± 3.6 min, representing 53 ± 27 % of calculated maximal acceptable work duration (13.2 ± 9.0 min). Peak blood lactate was 11.1 ± 3.9 mmol·L-1 or 99 ± 33 % of maximum.

Peak heart rate was 173 ± 11 b·min-1 or 93 ± 6 % of maximum, and peak RPE was 17 ± 2 or 94 ± 8 % of maximum. Swim task simulation VO2 was 36.7 ± 4.4 mL·kg-1·min-1, equating to 81 ± 12 % of VO2peak. Swim task duration was 10.2 ± 1.1 min, representing 47.6 ± 4.8 % of calculated maximal acceptable work duration (21.0 ± 15.6 min). Peak blood lactate was 8.1 ± 2.4 mmol·L-1 or 61 ± 18 % of maximum. Peak heart rate was 167 ± 15 b·min-1 or 103 ± 9 % of maximum, and peak RPE was 16 ± 2 or 80 ± 10 % of maximum. **Conclusions:** Paramedics performing land and water-based rescue from a helicopter are required to perform complex life-saving tasks at 80 to 85% of their maximal aerobic capacity for extended durations. The results of this study provide a foundation for task-to-test analyses for this occupation. **Military Impact:** Personnel staffing helicopter rescue teams are required to work at high physiological workloads and should undergo scientifically validated physical tests related to their job tasks to ensure capability.

Board 13: Alterations in gait markers during a timed ruck march using single inertial measurement unit

Vanessa J Ramirez [1], Peter Finch [1], Kyla Driver [1], Rebecca E Fellin [2], Mark Buller [1]

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Purpose: Musculoskeletal injuries (MSKIs) are the main threat to Army readiness and soldier health. Ruck marching and running are primary sources for knee, low back, and ankle injuries. Identifying gait changes with unobstructive equipment may provide an opportunity for early MSKI mitigation. This study examined gait parameters and how they changed over the course of a timed ruck march. **Methods:** This cross-sectional observational study, recruited nineteen male soldiers (mean ± SD; age = 24 ± 3 y; height =1.77 ± 0.07 m; body mass = 81.2 ± 8.4 kg) that took part in a timed (under 3-h) 12-mile ruck march with combat load (27.2 kg). Each participant was instrumented with one inertial measurement unit (IMU) (APDM, Portland, OR) on the left medial shank above the boot line. Step length, stance time, and cadence were measured. Yaw—the twisting around the vertical axis—tibial external rotation was derived from the magnetometer data by calculating a baseline vector using the mean of the previous three steps and then calculating the offset. Change in gait over time was examined during flat and uphill (> 3%) segments near the start and end of the march route. For each set of march segments (flat or uphill), variable means ± SD were compared using a paired t-test, with $\alpha < 0.05$. **Results:** There were no differences in cadence and stance time. Yaw did not change on the flat terrain but increased 2.1º (95% CI: 0.52 - 3.78, p = 0.006) on the last uphill segment compared to the first. Step length decreased at the end of the course for both the flat (mean difference: 0.06 m, 95% CI: 0.02 - 0.12, p = 0.01) and uphill segments (mean difference: 0.05 m, 95% CI: 0.02 - 0.09, p = 0.008). **Conclusions:** An IMU detected meaningful changes in gait during a timed ruck march, including increased yaw and decreased step length from the first uphill segment to the second. Changes in tibial rotation elucidate changes in hip and ankle rotation, which are both moderate predictors for injury risk during prolonged ambulatory tasks. This study also shows how terrain plays a role in gait deviations, which cannot be accounted for in laboratory-based (treadmill)

studies. **Military Impact:** Wearing an IMU during ruck marching may identify MSKI risk by tracking alterations in temporospatial gait parameters that may predispose soldiers to injury.

Board 14: Association of blood biomarkers to force-on-force engagement, small unit lethality, and in-field performance

Jason Soares [1], Chad R Straight [1], Meghan O'Donovan [1], Clifford Hancock [1], Kenneth Racicot [1], Laurel A Doherty [1]

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Purpose: There is an ongoing need to understand the near real-time physiological status of Warfighters, and at present there is no reliable objective measure of readiness or degradation during in-field operations. **Methods:** Fifteen dismounted infantry squads (n = 120 soldiers) were tested while conducting force-on-force engagements in a Battle Drill 2A (BD2A squad attack), which was repeated on three consecutive days. Squads underwent capillary finger blood sampling pre- and post-engagement to test for blood biomarkers (chemistries, electrolytes and haematology) traditionally associated with physical performance. Each squad was also rated on performance metrics (e.g., communication, fire effectiveness) by four military Observer Controllers to distinguish squads of varying proficiencies. **Results:** Analysis of variance revealed differences between squads in multiple biomarkers, including glucose, creatinine and anion gap (all $p < 0.05$). Net total carbon dioxide content (TCO2) of squad leaders correlated positively to overall ($\rho = 0.43$; $p = 0.017$) and specific performance ($\rho = 0.46$; $p = 0.011$) metrics, but collective metrics didn't correlate to squad summary statistics of blood biomarkers ($p \geq 0.055$). Squad leader net TCO2 also correlated positively to 9 of 15 performance component scores ($p < 0.05$). Pre-mission rehearsal scores were negatively correlated to squad leader net glucose ($\rho = -0.48$; $p = 0.009$), TCO2 ($\rho = 0.35$; $p = 0.019$), and squad mean glucose ($\rho = -0.31$; $p = 0.036$); positive correlation to dispersion of squad anion gap was also observed ($\rho = 0.34$; $p = 0.029$). Squad dispersion of net glucose also correlated to component scores on violence of action ($\rho = 0.42$; $p = 0.005$), but did not correlate with fire effectiveness, leadership, or surprise (all $p > 0.05$). Task component scores on consolidation of security positively correlated to dispersion of net creatinine ($\rho = 0.45$; $p = 0.002$) and urea ($\rho = 0.33$; $p = 0.028$), but negatively correlated to squad mean creatinine ($\rho = -0.32$; $p = 0.034$) and dispersion of anion gap ($\rho = -0.36$; $p = 0.019$). **Conclusions:** Using a minimally invasive approach to collect blood in a field setting revealed differences between squads in specific biomarkers, which are related to collective performance metrics. These results provide a roadmap for how biomarker-based in-field performance quantification can be accomplished in operational scenarios and identify physiological markers that may influence operational performance. **Military Impact:** Developing non- or minimally invasive physiological assessments will improve fieldable prediction tools for Warfighter readiness based on molecular biomarkers associated with performance.

Board 15: Weighted counter movement jump braking force variables in response to military specific load carriage

Christopher Vine [1], Steve McGuire [2], Sam D Blacker [1], Sarah Coakley [3], Oliver Runswick [4], Steve Myers [1]

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Purpose: The countermovement jump (CMJ) is widely used in occupational research to assess neuromuscular fatigue and performance. Improved force plate portability, technology, and affordability mean that high fidelity force data can be gleaned more routinely and in field-based scenarios. Changes in CMJ variables, which describe modifications in jumping strategies, have previously been used to profile neuromuscular fatigue. Recently braking force variables have been linked to injury risk clusters. The aim of this study was to investigate changes in CMJ braking force variables following treadmill load carriage. **Methods:** Twelve physically active civilian men (age, 27 ± 6 y; stature, 1.83 ± 0.05 m; body mass, 80.6 ± 8.0 kg; maximal oxygen uptake, 52.7 ± 5.5 mL·kg-1·min-1) completed three weighted CMJs (20 kg) on a pair of portable force plates (sample rate 1000 Hz). Measurements were taken pre-, post-, and 30-, 60-, 120-min post- walking on a treadmill carrying 25 kg of external load (20 minutes at 5.1 km·h-1; 40 minutes at 6.5 km·h-1, and; 8 × 9 s shuttles at 11 km·h-1 with 11 s recovery). The CMJ braking phase was identified from the point of peak negative velocity to the instant of positive velocity. Braking phase duration, average force, rate of force development (BRFD) and stiffness were calculated from the average of the three weighted CMJs at each measurement point. **Results:** A main effect for measurement point was observed for average force ($p < 0.001$, $\omega^2 = 0.013$), BRFD ($p = 0.002$, Kendall's $W = 0.364$), and stiffness ($p = 0.018$, $\omega^2 = 0.020$), but not for braking phase duration ($p = 0.116$, Kendall's $W = 0.154$). Specifically, average pre- to 120 min post-load carriage changes were 12.3% ($p > 0.05$) for braking phase duration, −4.7% ($p < 0.001$) for average force, −26.4% ($p = 0.017$) for BRFD, and −17.1% ($p = 0.022$) for stiffness. Attenuations at the other intermediary measurement points were typically progressive up to 120 min post-exercise. **Conclusions:** Collectively, these data show braking phase variables are compromised for at least two-hours following fast load carriage. Future investigations are required to further explore how likely undesirable changes in jump mechanics could impair military performance and / or increase injury risk. **Military Impact:** Force plates—and specifically CMJ variables—show the potential to be used as an easily employed indicator of physical performance readiness and injury mitigation within military populations; particularly given the development of software to automatically calculate CMJ variables.

Board 16: The relationship between isometric mid-thigh pull force-time characteristics and 2-km load carrying performance in trained British Army soldiers

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Purpose: Load carriage is recognised as a fundamental military occupational task. As such, the aim of this study was to assess the relationship between isometric force-time characteristics and loaded march performance. This study also aimed to investigate the relationship between isometric force-time characteristics and standing long jump (SLJ) performance. **Methods:** Thirty-nine, male British Army infantry soldiers (age 31 ± 6 y; height 1.76 ± 0.07 m; body mass 85.8 ± 11.5 kg) performed three isometric mid-thigh pull (IMTP) trials, three SLJ trials, and a 2-km loaded march carrying an external load of 25 kg. Within-session reliability between repeated trials was assessed via use of intra-class correlation coefficient (ICC) whilst the relationships between all variables were assessed using Pearson's correlation coefficient. **Results:** Both the IMTP (ICC [95% CI] = 0.96 [0.94 - 0.98]) and SLJ (ICC [95% CI] = 0.91 [0.84 - 0.95]) demonstrated an excellent level of reliability. However, isometric peak force (r [95% CI] = −0.06 [−0.37 - 0.26], p = 0.72), relative peak force (r [95% CI] = −0.14 [−0.43 - 0.19], p = 0.41), and rate of force development (r [95% CI] = − 0.14 [−0.43 - 0.19], p = 0.41), displayed only a small correlation with loaded march time to completion. In contrast, isometric relative peak force displayed a large positive relationship with SLJ performance (r [95% CI] = 0.55 [0.28 - 0.73], p < 0.01). **Conclusions:** Body mass, body composition, aerobic capacity, and lower and upper limb strength have all been identified as key determinants of load carriage performance. However, whilst dynamic measures of strength have been shown to display a strong relationship with load carrying ability, these data demonstrates that isometric force-time characteristics display only a trivial relationship. Indeed, data from this study demonstrate that absolute isometric peak force accounts for 0.03% and relative isometric peak force 1.80% of the total variance observed in 2-km loaded march performance. Given these findings practitioners should be aware that improvements in isometric force-time characteristics may not necessarily transfer to improvements in load carrying performance. However, relative isometric strength measures appear to demonstrate a strong relationship with standing long jump performance. **Military Impact:** The use of isometric force-time characteristics as proxy measures of load carrying ability should be questioned. However, relative isometric strength measures appear to demonstrate a strong relationship with standing long jump performance. Isometric testing may have utility in assessing explosive strength, monitoring neuromuscular fatigue, and assessing training readiness in military populations.

Board 17: Impact of combat equipment on respiratory muscle power during load carriage performance

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Purpose: Endurance performance is reduced during severe-intensity activity due to greater respiratory muscle power demands and the subsequent metaboreflex-response regulatory effect on locomotor blood flow. The purpose of this research was to investigate the effects of ground-based personal protective combat equipment configurations on respiratory muscle power during load carriage performance. **Methods:** Nine male Soldiers (Active-Duty, n = 5; Reserve Officer Training Corps, n = 4) having operational experience with body armour and load carriage (up to 38.5 kg) participated in this study's assessment procedures over 6 visits. Visits 1 - 2 gathered baseline data for maximal exercise metabolism, pulmonary function, and body composition. Visits 3 - 6, data was collected while participants performed a standardised load carriage protocol, i.e., Sustainment March (SMAR, 60-min with 1% grade at 5.6 km·hr–1). During the load carriage trials, subjects Power of Breathing (Pb, Joules per minute [J·min-1]) was assessed at five timepoints (time point 1 to 5 [TP1-TP5]) under four combat equipment configurations (NL, No Load = 0.0 kg; BA, Body Armor = 13.5 kg; LC, Load Carriage = 25 kg; BA+LC = 38.5 kg). **Results:** Repeated measure analysis of variance performed on SMAR TP15 Pb (Mean ± SEM, sample size; TP1 Pb = 70.06 ± 4.90 J·min-1, 34; TP2 Pb = 87.65 ± 6.65 J·min-1, 34; TP3 Pb = 95.06 ± 8.08 J·min-1, 34; TP4 Pb = 100.71 ± 9.90 J·min-1, 34; TP5 Pb = 105.47 ± 11.64 J·min-1, 34) revealed a statistically significant increase in respiratory muscle power over time ($F(1.407, 26069.32) = 19.08$, $p < 0.001$, $\eta^2 = 0.366$). Factorial analysis of variance identified statistically significant differences in Pb across configurations within timepoints (TP1 $F(3, 31) = 14.94$, $p < 0.001$, $\eta^2 = 0.591$; TP2 $F(3, 31) = 26.11$, $p < 0.001$, $\eta^2 = 0.716$; TP3 $F(3, 30) = 29.79$, $p < 0.001$, $\eta^2 = 0.749$; TP4 $F(3, 30) = 29.27$, $p < 0.001$, $\eta^2 = 0.745$; TP5 $F(3, 30) = 28.57$, $p < 0.001$, $\eta^2 = 0.741$). **Conclusions:** The increased scaling-weight in different combat equipment configurations increased the required respiratory muscle power necessary to perform standard sustainment load carriage task. **Military Impact:** This scientific knowledge-product improves the focal point of future science and technology efforts directed toward solving the Soldier's "lighten the load" issue, i.e., revise current PPE MILSPECs to include respiratory muscle power as an Indexed metric.

Board 18: A comparison between different military ranks' performance in a 3.2 km loaded march test

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Purpose: The military's need to use its biomotor capabilities during its work activities means physical training is a key element in maintaining the readiness levels of tactical athletes (military and public security agents). The assessment of physical performance in simulated tasks seems to be a good parameter for assessing readiness, however, the curricular differences that exist in training courses for soldiers and officers can generate discrepancies regarding the level of general physical readiness of the troops. This study aimed to verify differences between Brazilian Air Force (BAF) soldiers and cadets in their performance and physiological response in a 3.2 km loaded march test. **Methods:** Thirty-seven male members of the BAF (18 soldiers and 19 cadets, age 20.0 ± 0.2 y, 1.75 ± 0.01 m, 73.0 ± 1.9 kg) completed a 3.2 km loaded (14 kg) march test. The participants were rested and had to complete the established circuit as fast as possible without running. Total time, rating of perceived exertion (RPE), and heart rate (HR) (baseline and immediately after exercise) were collected. RPE showed a normal distribution and was compared using Student's t test for independent samples. Total time and HR variation were compared using Mann-Whitney U tests. The significance level adopted for the study was $p < 0.05$. **Results:** Total time (soldiers: 31.20 ± 0.47 min; cadets: 29.04 ± 0.68 min), HR variation (soldiers: 77 ± 4 bpm; cadets: 46 ± 4 bpm) and RPE (soldiers: 8.5 ± 0.2; cadets: 6.4 ± 0.2) showed significant differences between the groups ($p < 0.01$). Spearman's correlation test showed a moderate correlation between the HR variation and RPE ($r = 0.56$, $p < 0.001$). **Conclusions:** Were found significant differences between the soldiers and cadets related to perceived exertion and time spent performing a 3.2 km loaded march test. The number of field exercises in officer training courses may be related to better performance obtained by the cadets. **Military Impact:** To improve soldiers' physical readiness, the BAF's soldier training course could have a higher workload of field exercises and loaded marches.

Board 19: Performance of British Army personnel in a swimming representative military task

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Purpose: A job task analysis was undertaken with representatives of all British Army role-groups to evaluate job tasks involving working in and / or around water. Findings were used to inform the design of a new swimming representative military task (RMT), which was evaluated in an experimental trial to quantify: (1) best-effort performance, (2) test-retest reliability, and (3) differences between serving personnel and recruits. **Methods:** RMT performance was measured twice in a group of 103 serving personnel (89 men, 11 women) and once in a group of 65 recruits (49 men, 16 women). Whilst wearing fatigues and webbing, participants entered the water feet first until their head was submersed, removed and passed out webbing, swam 50 m, and then stayed afloat for up to 10 min. Performance was compared using independent sample t-tests and test-retest reliability was assessed using intra-class correlation coefficients (ICC), 95% confidence intervals, and limits of agreement (LoA). **Results:** In trial 1, 85% of serving personnel and 74% of recruits successfully completed all elements of the RMT, which increased to 93% in serving personnel for trial 2. Time to remove webbing (U = 3060.0, rb = −0.068, p = 0.463) and total time in water (U = 3319.5, rb = 0.011, p = 0.904) were similar between groups. On average, serving personnel were quicker to complete the 50 m swim than recruits (91 ± 24 s vs 100 ± 26 s; U = 2575.0, rb = −0.192, p = 0.039). Across trials 1 and 2, all three timed RMT elements showed moderate to high correlational reliability (ICC range: 0.462 to 0.791) with relatively wide LoA of −9 to 5 s, −31 to 26 s, and −213 to 267 s for time to remove webbing, 50 m swim time, and total time in the water, respectively. **Conclusions:** Performance data were used to inform the final test standard. A small learning effect was noted between trials 1 and 2, with performance improving on average during trial 2. Wide LoA meant that individual scores may vary on retests; suggesting familiarisation may be important. Total time in the water demonstrated the largest variation, which was largely influenced by the proportion of the 10 min afloat time that was completed. **Military Impact:** Implementing a regular swimming assessment that is reflective of in-service role requirements has the potential to improve operational effectiveness and reduce adverse events.

Board 21: The effect of marching speed on approximated centre-of-mass vertical movement during treadmill marching

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Purpose: Control of centre-of-mass (COM) vertical motion during gait is important. Too much or too little motion can increase metabolic and energetic cost. A monotonic relationship between walking speed and vertical COM movement has been demonstrated (loaded and unloaded), with greater displacement at faster speeds. However, this relationship has not been investigated in military personnel. Therefore, the aim of this study was to investigate soldiers' COM vertical motion during loaded marching across a range of military-relevant marching speeds. **Methods:** Seventeen Australian Army soldiers (5 females, 12 males; height 1.78 ± 0.09 m, body mass 81 ± 16 kg, age 25 ± 5 y) completed four 12-min walking trials on an AMTI dual-belt instrumented treadmill. Participants performed trials carrying 23 kg of external load at four walking speeds (3.5 km·h-1, self-selected [5.02 ± 0.24 km·h-1], 5.5 km·h-1, 6.5 km·h-1). COM

location was approximated using the midpoint of reflective markers attached to the anterior and posterior superior iliac spines of the pelvis that were tracked using a Vicon motion capture system (120 Hz). COM vertical movement was measured using the standard deviation and mean range (mean maximum - mean minimum) across 20 strides during the second minute of each trial. Linear mixed models were used to assess the effects of speed on these variables (□ = 0.05). Paired-sample t tests were performed where significant main effects were found. **Results:** There was a significant effect of speed on standard deviation ($p = 0.001$), whereby COM vertical position varied more as speed increased (mean ± standard error; 3.5 km·h-1: 11.6 ± 0.4 mm, self-selected: 17.4 ± 0.7 mm, 5.5 km·h-1: 19.2 ± 0.7 mm, 6.5 km·h-1: 22.1 ± 1.0 mm, $p = 0.001$). There was a significant effect of speed on mean range ($p = 0.001$), whereby it increased significantly with increasing speeds (3.5 km·h-1: 36.1 ± 1.3 mm, self-selected: 52.3 ± 1.9 mm, 5.5 km·h-1: 57.6 ± 2.1 mm, 6.5 km·h-1: 65.5 ± 3.0 mm, $p = 0.002$). **Conclusions:** In line with previous research in non-military populations, military personnel demonstrated a monotonic increase in vertical COM motion with increased speed. Participants possibly increased vertical COM displacement at faster speeds to reduce metabolic cost through mechanical energy exchange, but this speculation requires further research. **Military Impact:** Lower-limb strength training might help military personnel maintain or improve load carriage efficiency at faster speeds by improving mechanical energy exchange during marching.

Board 22: Temporal effect of backpacking on isokinetic variables in the knee joint after a 12 km simulated military road march: a pilot study

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Purpose: Due to the regular physical demands placed on military personnel, such as carrying external loads, they are known as tactical athletes. Mechanical stress on the lower extremities can impair combat performance. An Army task's primary stressors are load carrying and muscle exhaustion. This study investigated the temporal effects of a 12 km simulated road march (SRM) without (NL) and with (LC) backpack load (20 kg) on isokinetic variables in the dominant knee joint. **Methods:** Ten male military personnel (age: 19.2 ± 0.4 y; height: 173 ± 6 cm; body mass: 67.9 ± 6.9 kg; body fat: 16.8 ± 5.5 %) completed 3 days of evaluations (pre-test, LC, and NL) each separated by 7 days. Pre-test included body composition assessment, and isokinetic evaluations (60º s-1) in the knee flexor and extensor muscles (baseline). On the days of walking with LC and NL, a 12 km SRM was performed followed by a sequence (0, 2, 4, and 6 h) of isokinetic evaluations. The Shapiro-Wilks normality test was applied and confirmed the parametric approach. Repeated measures ANOVA with Dunnett's post-hoc was used to compare the pre vs post isokinetic parameters for NL SRM and LC SRM. Paired t-test was used to compare NL vs LC in the timeline after SRM. The level significance was $p < 0.05$. **Results:** In the LC condition, the post-SRM temporal effect on the peak torque (PT) normalised by the lean mass of the dominant lower limb (Nm·kg-1) was significant in knee extension (control = 22.8 ± 3.0 vs 2 h = 18.7 ± 2.8 Nm·kg-1, p = 0.04 and vs 6 h = 18.5 ± 2.7 Nm·kg-1, p = 0.03). At the same timepoint, in flexion, there was no effect. There was no post-SRM temporal effect on knee flexion and extension in the NL condition. The variables work in PT, time to PT, torque at 30º, torque at 0.2 s, and acceleration time changed post-SRM in knee flexion and extension in the NL and LC conditions. Intergroup analysis (NL vs LC) showed that there was no significant difference between 0, 2, 4, and 6 h. **Conclusions:** Adding load in a backpack generated neuromuscular impairment of the extensor muscles, and these muscle group should receive attention during military physical training. **Military Impact:** The velocity and load combinations should be managed to identify optimal recovery times, improve troop performance during LC, and mitigate its harmful effects on the neuromuscular function.

Board 23: Associations among body composition, performance, and military occupational demands

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Purpose: To identify whether the military occupational demands can be predicted based on the Soldier's performance and body composition. **Methods:** 1340 military personnel were used for analysis and allocated to two groups according to military occupational demands (Operational [Op, n = 732; age = 33 ± 0 y; body mass = 78.9 ± 0.4 kg] and Non-Operational [NOp, n = 608; age = 37 ± 0y; body mass = 78.6 ± 0.4 kg]). The sample were tested for body composition and performed the Brazilian Army Physical Fitness Test (BRAPFT). The ShapiroWilk test was used to analyse the normal distribution. Independent Student's t-test and Mann Whitney U test was used to test for differences between Op and NOp. Logistic regression was used to predict a categorical (Op and NOp) variable from a set of predictor variables (body composition and BRAPFT). The mean and standard error of the mean was used for descriptive statistics. **Results:** There was a significant difference in the abdominal circumference (NOp = 90.2 ± 0.3 cm; Op = 89.2 ± 0.3 cm; p < 0.001), fat percentage (NOp = 32.8 ± 0.2%; Op = 31.7 ± 0.2%; p = 0.04), waist circumference (NOp = 86.4 ± 4.3 cm; Op = 85.4 ± 3.2 cm; p = 0.03), 12-minute run distance (NOp = 2619.0 ± 12.7 m; Op = 2713.7 ± 10.3 m; p < 0.001), push-up performance (NOp = 28 ± 0 rep; Op = 30 ± 0 rep; p < 0.001), sit-up performance (NOp = 59 ± 1 rep; Op = 65 ± 1 rep; p < 0.001), and pull-up performance (NOp = 6 ± 0 rep; Op = 7 ± 0 rep; p < 0.001) were significantly different. The overall logistic regression model was statistically significant (X2(8) = 94.34; p < 0.05). The Hosmer-Lemeshow test showed a nonsignificant chi-square (Chisquare = 12.84; p = 0.117) and correctly classified 59.8% of cases, although the explained variation was 9.1 % (R2). Significant predictors were abdominal circumference (p < 0.001), 12 minutes run distance (p = 0.027), sit-up performance (p < 0.001), and body fat percentage (p < 0.001), but waist circumference (p = 0.904), hip circumference (p = 0.362), push-up performance (p = 0.055), and pull-up performance (p = 0.578) did not add significantly to the model. **Conclusions:** Operational personnel showed

better body composition and performance value than non-operational. There is a significant statistical significance in the comparison of the complete model with continuous models, which indicates that the predictors are consistently differentiated by Op and NOp. However, the correlation showed that there is a poor correlation between prediction and grouping. **Military Impact:** The maintenance of the physical readiness of military personnel should be managed following daily physical demands regardless of where the military is assigned.

Board 26: A new categorisation tool for physical fitness (CT-PF): efficient and valid assessment of physical performance in personnel recruitment and military medical assessments

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Purpose: High levels of strength, endurance, and speed are basic requirements for many physically demanding military tasks like marches or field training. Hence, adequate physical fitness is both a prerequisite for successful accomplishment (performance aspect) and an important factor in long-term maintenance of health and physical fitness (prevention aspect). Physical fitness is thus the basis for acquiring and maintaining operational readiness. For years, however, numerous unfavourable daily habits have been adversely affecting health, resilience, and physical fitness of the general population as well as many soldiers. Given the physical demands of military service, reliable procedures for determining physical fitness are becoming increasingly important for personnel recruitment and management or military medical assessments. The aim of the study was to develop a categorisation tool for physical fitness (CT-PF), with which physical fitness can be assessed and classified into performance categories based on easy-to-determine predictors. **Methods:** Predictors for strength, endurance, and speed were preselected and tested via multiple linear regressions against the standardized Basic Military Fitness Tool (BMFT) as a reference criterion. The BMFT reproduces a profile of general military requirements that was deduced from on-site analyses and was evaluated scientifically. The final parameter selection was made (1) regarding the variance of the criterion “BMFT total time” and (2) considering requirements in terms of personnel, time, material, and infrastructural resources. **Results:** Fat free mass, maximum isometric voluntary contraction of arm flexors and hand grip, sprint test, and 1000 m run of the Bundeswehr Basic Fitness Test, and gender explain over 70% of the variance (corrected $R2$: 0.71). The CT-PF predictors allow a sufficiently accurate characterisation of physical fitness with reference to a general military requirement profile. **Conclusions:** CT-PF is an efficient method for valid and reliable categorisation of physical fitness using a traffic light system “green-amber-red”. As it requires only limited resources in terms of time, personnel, material, and infrastructure, it is ideally suited for use in personnel recruitment and management or in military medical assessments. **Military Impact:** Using CT-PF even enables targeted support for soldiers in basic training. It opens up the possibility of tailoring training to suit target groups right from the beginning of basic training to optimise performance development and to reduce dropout rates. CT-PF can

provide valuable additional information for military medical assessments. The combination of health and performance data opens up a wide range of options when it comes to prevention, training and preparation for deployment.

Board 27: Repeated prolonged bouts of load carriage impact walking stability of soldiers

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Purpose: To determine the effect of repeated bouts of prolonged load carriage on walking stability using largest Lyapunov exponent (LLE) during a simulated 72-h mission. **Methods:** Seven male US Army infantry soldiers (age 24 ± 4 y, BMI: 26.8 ± 3.2 kg·m-2, body fat: 11.1 ± 2.5%) completed a five consecutive day protocol to simulate activities experienced during a 72-h mission with one day pre and post mission: baseline day (BASE), 72-h mission (MIS1-3), and one recovery day (REC). Tasks included simulated infiltration and exfiltration rucks, foot patrols, and react to contact scenarios. Data are presented for simulated ruck tasks performed on a treadmill on BASE and MIS1-3 days. Each day soldiers walked at constant speed of 1.35 m·s-1 for up to 2-h. An unloaded and loaded 10-min ruck (50% body mass loaded weight vest) at 0% incline on BASE, a loaded 2-h ruck at 0% (10-min), 3% (50-min), −3% (50-min), and 0% (10-min) inclines on MIS1 and MIS3, and a loaded 30-min ruck on at 0% (10-min), 3% (10-min), −3% (10-min) on MIS2. Multilevel models (MLMs) were used to determine the rate of change in the LLE calculated from sacrum acceleration during simulated rucking. **Results:** MLMs revealed that load carriage reduced LLE in the mediolateral (ML) direction by 1.35 SDs compared with the unloaded walk ($t_{6.0} = -4.011$, $p = 0.007$) during the 10min trials on BASE Day. Additionally, loaded walking reduced LLE in the anteroposterior direction by 1.19 SDs ($t_{6.0} = -3.419$, $p = 0.014$) relative to unloaded walking on BASE Day. Interestingly, LLE increased by 0.07 SDs/10 min during the 2-h ruck march during the MIS1 day ($t_{69.08} = 3.360$, $p = 0.001$). **Conclusions:** Movement trajectories become less divergent during load carriage, suggesting dampened or restrained lower back acceleration. Surprisingly, trajectory divergence increased throughout the loaded walk on MIS1, although trajectory divergence remained below 'normative' levels that were observed during unloaded walking during the initial BASE Day. Overall, gait dynamics seem to be modified by load carriage. Those modifications may be an indicator of fatigue that may increase injury risk. **Military Impact:** Load carriage is an essential military task. Soldiers often carry extreme loads on multiple days for prolonged periods in both training and mission scenarios. Much attention has been paid to the problem of detecting injury indicators during loaded gait; however, no clear solution has been established. This research suggests that nonlinear analysis of movement trajectories may be a potent biomarker to track changes in walking stability that may indicate injury risk.

Board 28: Effects of head borne loads on helmet stability during a simulated tactical shooting task

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Purpose: Helmet stability is critical when performing operational tasks that require the use of Night Vision Goggles (NVG's). Different helmet load configurations have the potential to influence helmet stability during these tasks. This study investigated the influence of different head borne load configurations on helmet stability during a simulated tactical shooting task. **Methods:** Six experienced tactical shooters were asked to perform a simulated dynamic tactical shooting task in which there were three targets located in front of them. They were asked to engage the target immediately in front of them, then neutralise a secondary target that was located 60º to either the right or left of the first target. Both secondary targets presented at the same time and involved a discrimination task in which only one was to be engaged. This task was repeated four times (twice with a "friendly" target appearing to the right, twice with it appearing to the left) under three conditions: 1) while wearing a ballistic helmet with no load (HEL), 2) while wearing a helmet with deployed PVS-31 NVG's (DEP-NCW), and 3) while wearing deployed NVG's with counterweight (DEP-CW). During the shooting task, average helmet stability (helmet motion relative to the head) was quantified using 3D motion capture in the frontal (roll) and transverse (yaw) planes from initiation of the task to final shot. **Results:** Although helmet motion associated with roll tended to be larger than yaw across all conditions ($p = 0.057$), it was only significantly larger ($p = 0.038$) in the DEP-NCW condition (mean ± SE: 1.51 ± 0.37º vs 0.65 ± 0.11º, respectively). Within motion measures, there was no significant difference between loading conditions for roll ($p = 0.380$). There was a significant difference across conditions for measures of yaw, with the unloaded HEL condition experiencing less motion ($p = 0.046$) than the DEP-NCW condition (0.34 ± 0.07º vs 0.65 ± 0.11º, respectively). Yaw measure of motion were similar for the DEP-CW condition (0.52 ± 0.09º) but was not significantly different than the HEL condition ($p = 0.063$). **Conclusions:** For the operational task performed, more helmet instability was associated with roll, but does not appear to be influenced by helmet load; there is less motion associated with yaw, but yaw does appear to be influenced by helmet loading. Both have the potential to adversely affect eye alignment while using NVG's **Military Impact:** Understanding the implications of how loads affect equipment usability is of vital importance when quantifying performance and survivability of the warfighter. Helmet instability while wearing NVG's has greater operational implications than other head borne loads due to potential for compromised eye alignment.

Board 29: The effect of muscle activity on shooting accuracy

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Purpose: Evaluation of small-arms weapons, including assault rifles, is generally undertaken under controlled, static conditions, reducing the impact of the human on weapon performance. As most weapons tested in this way show little difference in accuracy, metrics that better identify the interaction between the weapon and the human are needed, and muscle activity may be a suitable method. The current study aims to understand the relationship between muscle activity and shooting accuracy. **Method:** Eighteen M4 qualified males used an M4 rifle from the low-ready position, aligned the rifle with the target to shoot, returned to the low-ready, and repeated 60 shots "as fast as they accurately could". Electromyography (EMG) was collected from eight bilateral sites in the 200 ms before each shot and normalised to a maximal contraction. The 60 shots were repeated four times using different weapon configurations. Support hand position (SHP) on the weapon was categorised based on the anteroposterior position along the barrel (SHP1 proximal to SHP3 distal). A linear mixed model was built using jamovi with accuracy as the dependent variable, muscle activity and SHP as fixed factors, and participant as a random effect. **Results:** Accuracy was better with lower levels of EMG in the right upper ($p < 0.001$) and mid trapezius ($p = 0.040$), and right bicep ($p < 0.001$). Accuracy was worse with lower levels of EMG in the right brachioradialis ($p = 0.002$). Each muscle except biceps were affected by SHP and in each case SHP2 was significantly less accurate than SHP1. Irrespective of SHP, accuracy decreased by 2.3 mm per 1% increase in EMG for right upper trapezius, 1.5 mm for right mid trapezius, 3.3 mm for right bicep, and improved by 5.1 mm for every 1% increase in EMG in right brachioradialis. **Conclusions:** EMG of the shooting side is related to accuracy, as is SHP, likely because of the effects on the quality of the trigger pull. Increased accuracy with increased right brachioradialis activity and lowered activity in other muscles was only significant in SHP2 and may be related to pulling the weapon into the shoulder to increase stability. We hypothesise that SHP1, which partially consists of the support hand wrapping around the magazine-well, allowed the shooter to stabilise the weapon easier. **Military Impact:** Optimising the support hand position should be considered when procuring a new assault rifle, and muscle activity may be used as a metric to inform procurement decisions.

Board 30: Training and education on fitting and adjusting body armour: implications for body armour fit

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Purpose: A high prevalence of ill-fit has been reported among Australian male (22%) and female soldiers (64%) wearing current issue body armour systems, which can affect operational

performance. Although fit-related issues have been attributed to body armour design and sizing limitations, previous research with female soldiers suggests that insufficient training on fitting and adjusting the system may confound fit-related problems. **Methods:** 77 male and 31 female soldiers (mean age: 23 ± 5 y; mean time enlisted: 4 ± 4 y) from the Australian Army answered questions about the training and education that they received on fitting and adjusting their body armour system. A subset of participants (20 male and 15 female) participated in a series of focus groups, in which participants spoke about their experience with body armour, including training and education. **Results:** 27% of participants did not feel that they received sufficient training on how to fit their body armour system. In the focus groups, participants noted that they 'were given a video [tutorial on how to assemble their body armour], but it didn't really work' and many were left with incorrectly adjusted systems that were either 'really painful', or unsafe due to 'the quick release being put together wrong'. These issues were more commonly reported by female soldiers, who tended to experience more difficulty with fit and adjustment of the system in general—'it would have been beneficial if one of our female small group instructors had come around and [given] us some tips or something…a lot of the stuff that I experienced, my male peers did not.' Another participant noted that the videos alone may not be sufficient to understand individual adjustment on a new system, but rather that 'an actual physical lesson' may be required. **Conclusions:** Based on feedback from soldiers it is reasonable to presume that some instances of reported ill-fit may be relieved by providing additional support and training to soldiers about how to assess system fit and adjust their own body armour. **Military Impact:** Although evidence supports the need for design modifications and expansion of the current sizing range to improve fit of body armour systems, a more immediate and cost-effective solution to relieve some prevalence of ill-fit reported by some soldiers may be the implementation of educational programs that inform users about correct fit and adjustment of their body armour systems.

Board 31: Accuracy of mission specific military variant wearable ECG monitor compared to existing clinical and commercial monitors

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Purpose: Physiological monitoring of soldiers can provide indicators of readiness and performance. Specifically, electrocardiogram (ECG) is used to measure physiological stress via heart rate (HR) as well as fatigue using heart rate variability (HRV). Despite demonstrated use of wearable devices for ECG monitoring, commercial options lack features desired for military use such as ruggedness, extended battery life, and long-range secure data transmission. Recently, the Mayo Clinic has designed a chest-worn physiologic monitor (OMNI), which records high-resolution data from multiple sensors and include the above desired military features. This study investigated the accuracy of the OMNI relative to a clinical-grade ECG as well as existing commercial sensors. **Methods:** 54 young, healthy individuals (men / women

= 37 / 17, age = 22.2 ± 3.6 y, height = 1.73 ± 0.09 cm, body mass = 70.1 ± 11.2 kg) completed a submaximal graded exercise test while wearing a ground-truth clinical grade ECG monitor (Biopac) and a randomly assigned chest-based ECG monitor (OMNI, Polar H10, Equivital EQ-02, Zephyr Bioharness 3). All participants also wore two wrist-based photoplethysmography (PPG) devices (Garmin Fenix 6 and Empatica E4) on randomly assigned wrists. Bland-Altman analyses of agreement, concordance correlation coefficient (CCC), and root-mean-squared-error (RMSE) were used to determine the accuracy of the RR interval duration of each device relative to clinical ECG. Additionally, linear mixed modelling was performed to measure the effects of device and exercise intensity on error. **Results:** Chest-based devices showed superior agreement with Biopac compared to wrist-based in terms of mean bias, CCC, and RMSE, with OMNI demonstrating the best scores on all agreement metrics. The linear mixed model showed no significant main or interaction effects for the chest-based devices. However, significant effects were found for Garmin and Empatica devices ($p < 0.001$) as well as the interaction effects between both Garmin and Empatica and exercise intensity ($p < 0.001$). **Conclusions:** The OMNI device shows excellent agreement with clinical ECG and is at least as accurate as other commercial ECG monitors. Additionally, our results demonstrated that wrist-based PPG devices are significantly less accurate than chest-based ECG devices and show proportional bias as they tend to underestimate HR at low exercise intensities and overestimate HR at high exercise intensities. **Military Impact:** Chest-based ECG devices are preferred over wrist-based PPG devices for soldier physiological monitoring due to superior accuracy over a range of exercise intensities. The OMNI device presents as an attractive option due to its excellent agreement with clinical-grade ECG and suite of additional military-relevant features.

Board 32: U.S. Army Medical Research and Development Command Military Operational Medicine Science and Technology Research Program overview

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Purpose: U.S. Army Medical Research and Development Command Military Operational Medicine Research Program (MOMRP) mission is to support readiness of the force across the lifecycle of the warfighter. MOMRP is the science and technology planning and budgeting activity for knowledge and materiel products to develop effective biomedical countermeasures against operational stressors and to prevent physical and psychological injuries during training and operations to maximise the health, readiness, and performance of Service members and their families. **Methods:** The objective is to provide an overview of MOMRP related to warfighter performance and readiness. **Results:** MOMRP strategically plans for and executes research and development across four research focus areas: 1) Environmental Health and Protection focusing on environmental and occupational contaminant exposure monitoring and health assessment, and human performance optimisation in extreme environments. 2) Injury Prevention focusing on the neurosensory system, including hearing loss and vestibular issues; musculoskeletal injury prevention, treatment, and rehabilitation; and development of exposure standards for repeated blast exposures. 3) Physiological Health and Performance focusing on fatigue mechanisms and countermeasures, to include cognition and performance enhancement, and the

role of nutrition in physical performance and recovery. 4) Psychological Health and Resilience focusing on psychological disorders, substance abuse, and suicide prevention. **Conclusions:** As global militaries develop novel concepts for the future warfighter, joint collaboration on core concepts will function as a force multiplier and aid in the realisation and implementation of these capabilities. **Military Relevance:** The Program Area Managers will relay information on the mission, vision, capability gaps, and current efforts, which can be addressed by subject matter experts in the field to provide innovative medical solutions to the warfighters.

Board 33: Psychophysiological changes observed during military tasks in a training subterranean compound

Mickey Scheinowitz [1], Yuval Eshed [1], Meir Ore [2], Eden Avital [1], Dan Grinstein [1], Itay Ketko [3], Tom Zalmenson [1], Yair Bar-Haim [1]

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Purpose: Data regarding soldiers' strain under subterranean environments (SubT) is scarce. This study aimed to investigate the psychophysiological strain associated with performing military tasks in SubT. **Methods:** Thirteen active duty and trained male soldiers signed an informed consent form after the study protocol was approved by the Israeli Defense Force Medical Crops Institutional Review Board Committee. The participants were exposed to a 200 m SubT and were required to operate a stretcher or disassemble / assemble a weapon as fast as possible. SubT conditions were monitored for O_2 and CO_2, and were normoxic, with minimal light. There was no control group. Before entering the SubT, during, and after exiting the SubT the participants underwent cognitive tests using the Flanker task, subjective measures of anxiety (VAS, visual Analog Scale) and Ratings of Perceived Exertion (RPE), blood lactate levels, and continuous measurement of heart rate (HR) and gas exchange (VO_2, VE) using the K5 device (COSMED). Post-SubT values were compared with pre-SubT values within the same participants. **Results:** HR was significantly increased from 115 ± 8 $b \cdot min^{-1}$ to 162 ± 10 $b \cdot min^{-1}$ during the SubT and decreased to baseline values (109 ± 10 $b \cdot min^{-1}$) after exiting the SubT. VO_2 was also increased from 754 ± 90 $mL \cdot min^{-1}$ to 2201 ± 479 $mL \cdot min^{-1}$ during the SubT and decreased to pre-values after exiting the SubT. VE was increased to a maximal value of 67 ± 9 $L \cdot min^{-1}$ at the SubT and returned to baseline values after exiting the SubT. The RPE was increased from 1 ± 1 to 4 ± 2, while anxiety and VAS scales were unchanged. Flanker results were not significantly changed. Blood lactate was, however, significantly increased from 1.3 ± 0.5 to 7.2 ± 3.5 $mmol \cdot L^{-1}$ and was 4.8 ± 1.9 $mmol \cdot L^{-1}$ even 10 minutes after exiting the SubT. **Conclusions:** Both objective (HR, VO_2, VE) and subjective (RPE, VAS) measures of exertion reflected low aerobic strain in a training SubT compound. However, lactate levels were significantly elevated and remained high even during 10 minutes of recovery after exiting the SubT. Additional investigation is warranted to understand the slow recovery pattern of blood lactate and its impact on performance in subsequent activities. **Military Impact:** SubT induces mental and cognitive strain in addition to physiological strain which may impact subsequent

activities. The current data may aid in suggesting improved operational competence of the combat soldiers by optimising their physical and mental training processes.

Board 34: Evaluation of the physical demands of logistic soldiers in the Swedish Armed Forces

Lena Norrbrand [1], Roger Kölegård [1], Antonis Elia [1], Michail E Keramidas [1] Mikael Grönkvist [1], Björn Johannesson [1], Dilja Sayfulaeva [1], Lars Berg [1], Ola Eiken [1]

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Purpose: In the process of improving performance and reducing injury risk for soldiers in the Swedish Armed Forces, specific training regiments and tests need to be developed. The tasks conducted by a logistic soldier may include handling delivery of food, water, fuel, supplies, and ammunition to other soldiers in the field. Thus, this study assessed the physical demands experienced by logistic soldiers during a single regular task and two common soldiering tasks, which are considered physically demanding. **Methods:** Three tasks were chosen for testing; 1) loading of food supply into a truck: 96 boxes (~12 kg / box) were lifted, carried 10 m, loaded on a truck (height 1.3 m), stacked on pallets (maximum height 1.6 m), and secured; 2) stretcher carry: soldiers ran 300 m, lifted the casualty (dummy 101 kg) onto a stretcher, which was carried back 300 m, and; 3) digging: soldiers dug a fox hole in forest terrain. Twelve logistic soldiers (3 women, 9 men) performed the tasks at a regiment in the south of Sweden. Loading the truck and stretcher carry were performed in a group of two while wearing full combat uniform. Digging a fox hole was performed in a group of three while wearing boots, trousers, and a T-shirt. Time to finish, oxygen uptake (VO_2; $L \cdot min^{-1}$) and heart rate (HR; $b \cdot min^{-1}$) were measured in all soldiers, except for VO_2 during digging ($n = 8$). VO_2 and HR were averaged across the entire task. Ratings of perceived exertion (RPE; scale range: 6-20) was obtained from all soldiers immediately after the tests. **Results:** Loading of food supply into a truck (26 ± 3 min) resulted in a VO_2 and HR of 2.7 ± 0.6 $L \cdot min^{-1}$ and 178 ± 12 $b \cdot min^{-1}$, respectively. During the stretcher carry, the soldiers worked for 14 ± 2 min at 2.7 ± 0.5 $L \cdot min^{-1}$, and at 169 ± 10 $b \cdot min^{-1}$. Furthermore, during digging the soldiers worked at 2.3 ± 0.5 $L \cdot min^{-1}$, and at 160 ± 9 $b \cdot min^{-1}$ for 40 min. RPE was self-reported as "hard/very hard" for loading of food supplies into a truck (16, range: 14-20), stretcher carry (16, range: 13-19), and digging (16, range: 13-19). **Conclusions:** The regular tasks of the logistic soldiers may be at least as physically demanding as common soldiering tasks, which are performed within the Swedish Armed Forces. **Military Impact:** The physical demands of soldiers' regular, occupation-specific tasks should be considered when creating strength and endurance exercise programmes.

Board 35: Using heart rate within a squad to predict squad cohesion

Victoria G Bode [1], Jayne Allen [2], Kevin O'Fallon [1], Clifford Hancock [1], Prsni Patel [3], Julie Cantelon [1], Seth Elkin-Frankston [1]

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Purpose: The future Army operating concept emphasises optimisation of soldier and squad performance. Predicting squad cohesion (i.e., trust and adaptability to the situation, one another, and mission accomplishment) will become increasingly important; however, it is unclear how to predict squad cohesion using quantitative metrics. Physiological status can be derived from heart rate data collected by devices soldiers commonly wear (e.g., fitness watches). Previous literature has seen a relationship between heart rate and trust, and by further linking squad cohesion and heart rate, squad leaders and unit commanders would have better insight into squad performance and support better mission planning. To evaluate this relationship, we investigated the interaction between physiological status derived from heart rate and squad cohesion. **Methods:** 161 participants across fifteen squads participated in a 72h field exercise which included an infiltration and exfiltration ruck march, during which squad cohesion and physiological status were assessed. Squads rucked while wearing their full kit, including helmets and weapons (averaging 37 kg). Soldiers' self-reported team processes such as adaptability, efficacy, and trust before, during, and after the 72-hour mission. Heart rate was collected using a chest physiological status monitor and synchronisation was calculated using the root mean square deviation of individuals heart rates to the squad average. A bivariate correlation was used to find relationships between squad cohesion scores and soldier heart rate root mean square deviation during the infiltration and exfiltration rucks, respectively. **Results:** The heart rate synchronisation was calculated for all squads (mean ± SD; infiltration: 6.99 ± 3.31 $b \cdot min^{-1}$; exfiltration: 5.28 ± 5.28 $b \cdot min^{-1}$) with a range of 1.51-17.47 $b \cdot min^{-1}$. While no significant correlations were found for the infiltration ruck, the exfiltration ruck was correlated to pre-mission adaptability ($r = -0.209$, $p = 0.039$) and emotional strain ($r = 0.338$; $p = 0.027$). **Conclusions:** Squad heart rate synchronisation during a ruck march may be related to pre-mission team adaptability and emotional strain. While heart rate trends seem to be similar within a squad over the mission duration, factors such as terrain, squad fitness levels, and age may be more important contributors to the relationship than squad cohesion. **Military Impact:** Using heart rate to predict qualitative metrics, such as squad cohesion, would allow leadership to make more informed decisions during mission planning. As heart rate is readily available on most commercial devices, obtaining heart rate values is easy and cost effective per soldier and should be considered when looking for a predictive metric.

Board 36: Oxygen uptake (VO_2) and pulmonary ventilation (V_E) during military surface fin swimming in a swimming flume: effects of surface immersion

Olivier Castagna [1], Jean-Eric Blatteau [2], Arnaud Druelle [3], Jordan Amara [4], Jean-René Lacour [5]

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Purpose: During military fin swimming, we suspected that oxygen uptake (VO_2) and pulmonary ventilation (V_E) might be higher than what is commonly known (used) in the military diving community. In this framework, we compared these variables in the responses of trained military divers during land cycling and snorkelling exercises. **Methods:** Eighteen male military divers (age 32.3 ± 4.2 y; height 1.78 ± 0.05 m; body mass 76.4 ± 3.4 kg; BMI 24.1 ± 2.1 kg·m-2) participated in this study. They performed two test exercises on two separate days: a maximal incremental cycle test (land condition) and an incremental fin swimming (fin condition) in a motorised swimming flume. **Results:** The respective fin and land VO_{2max} were 3.70 ± 0.39 L·min-1 and 4.03 ± 0.63 L·min-1 ($p = 0.07$) and these values were strongly correlated ($r2 = 0.78$, $p < 0.01$). Differences in VO_{2max} between conditions were large for those with larger land VO_{2max}($r2 = 0.4$ $p = 0.01$). Fin V_{Emax} values were significantly lower than land V_{Emax} values ($p = 0.01$). This result was related to both the significantly lower land tidal volume (Vt) and breath frequency (f) ($p < 0.01$ and $p < 0.04$, respectively). Consequently, the fin V_{Emax} / VO_{2max} ratios were significantly lower than the corresponding ratios for land values ($p < 0.01$) with the fin and land V_{Emax}not correlated ($r^2 = 0.28$, $p = 0.523$). Other parameters measured at exhaustion, especially the indicators of haematosis, were similar in fin and land conditions. Furthermore, no significant differences between land and fin conditions were observed for peak values for heart rate, blood lactate concentration, and respiratory exchange ratio. **Conclusions:** Surface immersion did not significantly reduce the VO_{2max} in trained divers relative to land conditions. As long as VO_2 remained below VO_{2max}, the V_E values were similar in the two conditions. Only at VO_{2max} was V_E higher on land. Although reduced by immersion, V_{Emax} provided adequate pulmonary gas exchange during maximal fin swimming. We hypothesise that the lower fin V_{Emax} does not impair performance, but rather that it corresponds to an appropriate adjustment linked to enhanced pulmonary vascularisation. **Military Impact:** The results presented here suggest that the ventilatory regime of military divers may exceed the limits set by scuba breathing apparatus standards, but this conclusion will need to be confirmed.

Board 45: Evaluating sleep patterns and perceptions of sleep quality between British Army basic training programmes

Alex J Rawcliffe [1], Shaun Chapman [2], Andrew J Roberts [1]

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Purpose: Achieving good quality sleep is critical to optimal cognitive and physical performance during basic training (BT), yet routine sleep restriction and poor sleep quality are frequently observed. The Army's BT programme is frequently reviewed and subsequently modified relative to changes in focus, policy and/or practice. The most recent Common Military Syllabus 21 (CMS21) suggests greater opportunity for improved sleep duration by reducing the volume of evening activity from that of the previous BT programme (CMS18). To assure these sleep-related changes, this study evaluated recruit sleep patterns and perceptions of sleep quality between CMS21 and CMS18. **Methods:** Full data sets from 93 (CMS18) and 122 (CMS21) recruits (age: 23 ± 5 y) were used for analysis. Participants wore a sleep ring each night of BT with sleep indices extracted from propriety software and visualised using a custom R script. Perceptions of sleep quality and sleep disturbances were recorded and later extracted from a weekly online

sleep questionnaire for descriptive analysis. A mixed-model ANOVA determined differences in objective sleep indices between CMS course and training week (week 1-12). **Results:** Total sleep time (TST) (~30 min) only statistically differed (bi-directional) between CMS courses for a small number of BT weeks (weeks 1, 7, and 8). Despite these differences, TST was similarly inadequate during both CMS courses (mean ± SD, 05:48 ± 00:45 hh:mm), with > 80% of participants experiencing substantial sleep restriction relative to national recommendations (7-9 h per night). The weekly average time in bed (TIB) recorded during both CMS courses was ~06:30 hh:mm with a 22:30 ± 02:10 hh:mm bedtime and a 05:00 ± 01:06 hh:mm wake-time, thereby demonstrating poor sleep scheduling. The weekly average time spent awake (after falling asleep) was 01:19 ± 00:10 hh:mm, with noise (45%), stress / anxiety (19%), and muscle soreness (14%) reported as the most common sleep disturbing factors during both courses. Routine early morning wake times (≥ 0400 h) and late-night military admin were identified as other key factors preventing adequate TIB, and by extension, TST. All participants took ~10-15 min to fall asleep at night, suggesting high levels of sleep pressure and why >77% of all participants reported falling asleep "with ease". **Conclusions:** There is no evidence to suggest that changes made within CMS21 improved recruit sleep duration or quality from CMS18. Military Impact: Sleep should be recognised as a critical component of Army BT given the magnitude of sleep restriction observed. Prioritising better sleep duration and quality is likely to enhance the health, performance, and lived experience of recruits during BT.

Posters 1: Futures Science and Technology

Tuesday 12th September, 13:15 to 14:45

Board 37: Energy expenditure during operational circumstances: an approach using and improving available monitoring systems recently trialled in units of the Dutch Armed Forces

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Purpose: Light infantry units, such as the Royal Netherlands Marine Corps and the Dutch Airmobile Brigade, face challenges in isolated environments with limited supplies. To optimise tactical decision-making and mitigate exhaustion, real-time monitoring of energy expenditure (EE) can be crucial. This study aims to evaluate and select suitable monitoring systems within the Dutch Ministry of Defence (MoD) for monitoring EE. **Methods:** A narrative review of literature on monitoring systems in the Western military was conducted. Additionally, technical inquiries were made to assess the monitoring systems currently used within the MoD. Iterative trials with advanced monitoring systems are planned. A six-month validation study will be conducted, comparing wearables with the COSMED K5 as a reference standard for EE measurement. **Results:** The literature review identified distinct categories for monitoring systems requirements: sensors, functionalities, specifications, data quality, and applicability / limitations. Data security was incorporated due to MoD emphasis. Out of nine available systems, two exhibited the maturity and capability to address these specific requirements. The key components encompassed technology readiness level, functionalities, and data security, which, when combined, will result in a high-quality monitoring system suitable for further research. **Conclusions:** Though the two systems had different emphases on performance, an integrated system shows promising potential for real-time monitoring in military contexts. The next stage of this study will focus on testing this integrated system for data security and valid sensor information during EE measurement under operational circumstances. **Military Impact:** This method of evaluating, selecting, combining, and assessing existing systems presents an alternative to the lengthy and expensive process of acquiring new products. The findings will contribute to making informed decisions on improving accessible monitoring systems. The current monitoring systems will be presented, including their specifications and the criteria that we applied to select the best two systems for monitoring EE.

Board 38: Using a novel multi-array facial electromyography for fatigue evaluation during an anaerobic exercise test

Itay Ketko [1], Rawan Ibrahim [1], Yael Hanein [1], Mickey Scheinowitz [1], Itay Ketko [1], Rawan Ibrahim [2], Yael Hanein [2], Mickey Scheinowitz [2]

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Purpose: Facial expressions quantification through surface electromyography (sEMG) have a great potential in fatigue evaluation. Yet, this topic has not been widely studied, apparently due to a technological gap that does not allow convenient and accurate measurement during exercise.

Recently, a new flexible multi-array electrode sensor was developed, allowing high-resolution and long-term recording. The aim of the current study was to use facial electromyography for understanding the "expression of effort" during an anaerobic exercise. **Methods:** Five healthy (age 31 ± 3 y) and recreationally active participants (two men) performed the Wingate anaerobic cycling exercise test. Facial sticker, covering the forehead, zygomatic, buccal, nasal, and labial regions by 16 embedded electrodes was used for continuous recording of sEMG signal throughout the exercise and during the recovery period. Peak and mean mechanical power output were calculated. The root mean square (RMS) of the sEMG signal recorded from each electrode was calculated, and then averaged along the exercise. Paired t-tests were used to analyse differences in RMS and facial expressions. **Results:** Peak and mean power outputs were 513 ± 139 W and 396 ± 89 W, respectively. The average RMS reached a maximal value of 150 ± 37 µV at the peak power phase, compared with 126 ± 41 µV at the mean power phase ($p < 0.05$). There was a strong positive correlation between the mechanical power output and the RMS (Spearman rho = 0.62). A gradual decrease in RMS was measured during the recovery period presenting a significant difference between the first minute of recovery and the rest prior to the test (28 ± 5 µV and 16 ± 2 µV, respectively, $p < 0.01$). However, after the second minute of recovery, the RMS returned to rest values (18 ± 3 µV, $p = 0.2$). Non-frowning muscles activity was more dominant than frowning along the test ($p < 0.05$). However, only non-frowning muscle activity differed between peak power and mean power output phases ($p < 0.05$). **Conclusions:** Our sEMG sticker is highly stable during short and intense exercise. Spatial and temporal differences in facial expression were detected during this short and intense type of exercise along with the increase in the mechanical power outputs. We do not know yet whether facial sEMG signal follows the muscles activity or vice versa; further studies are needed to address this question. **Military Impact:** Identifying soldiers' fatigue during exercise or demanding cognitive tasks is important for avoiding over-training, and to maintain readiness. Once the "face of effort" is fully understood, we will be able to monitor, in real-time, fatigue related measures in a military oriented environment.

Board 39: A mixed-reality environment for the assessment of situational awareness of the dismounted soldier

Ivo Stuldreher [1], Nienke de Groes [1], Birgit van der Stigchel [1], Jikke Reinten [1], Maarten Michel [1]

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Purpose: Soldiers in the field are increasingly presented with information technologies, such as military smart phones and augmented reality. These technologies are in part aimed at enhancing the situational awareness (SA) to optimise performance. Therefore, it is important to measure to what extent an information technology impacts the soldier's SA. However, measuring a soldier's SA in realistic scenarios proves difficult. Therefore, we aim to develop a standardised mixed-reality environment where the SA of the dismounted soldier can be assessed under the addition of new information technologies. **Methods:** At the basis of the environment lies the Mobile Immersive Cognitive Environment (MICE), a mixed-reality setup consisting of a self-paced treadmill surrounded for 180° by five 4K UHD 75" monitors on which the virtual mission environment is presented. The user can move around in the virtual environment by walking on the treadmill, while using real-world devices, such as an augmented reality headset. The user has to avoid detection by enemy aerial and surface drones, while performing a realistic task. SA is assessed both through task performance and filling out in-situ SA questionnaires during the task. **Results:** The mixed-reality research facility was successfully piloted with SMEs. Custom software was developed in collaboration with MultiSIM, using their D-SIM framework. Two scenarios, an urban reconnaissance and navigation task, were developed in which the SA of the dismounted soldier can be assessed implicitly (e.g., how much of the assigned area has been reconnoitred and how often the user has been detected). Additionally, standardised events were developed through which greater insight is obtained in specific aspects of SA. For instance, the unexpected appearance of a drone was included to assess reaction time and decision making and an ambush is used to assess the predictive ability. **Conclusions:** Our environment allows for testing the impact of novel information technologies on SA of the dismounted soldier in relevant, realistic scenarios, while retaining control of events. The two current scenarios and multitude of events allow for varied yet comprehensive assessment of SA. A next step is to validate our measures of SA and establish baseline values for SA. **Military Impact:** With this environment, we aim to contribute to the enhanced information position of our dismounted soldier. Our environment can serve as a test-bed, where the impact on SA of novel information technologies can be tested quickly and comprehensively, to enhance the development process of such technologies.

Board 40: Emerging methods for quantifying human-system performance with automatic small arms platforms

Frank Morelli [1], Maria Talarico [1], Francis J. Battersby [2]

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Purpose: Data loss is commonplace for automatic burst firing due to typically wider dispersion patterns. This effect makes reliable characterization of shot group spatial localization difficult, with data loss exacerbated at extended distances. **Methods:** Acoustic targetry featuring two expanded acoustic envelopes were used to characterize dispersion patterns at multiple ranges. Two weapons were used: (1) M240 medium machine gun and (2) M249 squad automatic weapon. Shooters completed 5- and 7-round bursts with rest between trials. Hit count was calculated as a percentage of shots collected and total shots taken. Shooters fired at targets from 300 m to 600 m to determine whether the targetry could gather data at each distance. Descriptive statistics and one-way ANOVAs were performed to determine effects of range on shot groups and mean radial error (MRE). Tukey HSD post hoc analysis was conducted for significant main effects (a priori a: $p \leq 0.05$). **Results:** For M240 trials, a larger percentage of shots was recorded at 400m (42% [5rds], 75% [7rds]) than 300m (38% [5rds] and 45% [7rds]), with no data collected beyond 400 m. For M249 trials, shot recording decreased as range increased (main effect of range on shot % [$p < 0.001$]). Post hoc testing indicated shot percentage at 500 m differed from 300 m ($p < 0.001$) and 400 m ($p = 0.03$). No significant difference was observed between 300 m and 400

m ($p = 0.053$). As target range increased, MRE of all shots collected decreased ($p < 0.001$). MRE at 500 m was smaller than at 300 m ($p < 0.001$) and 400 m ($p < 0.01$). Average MRE of shots at 300 m did not significantly differ from 400 m ($p = 0.32$). When accounting only for hits, MRE was unchanged across ranges ($p = 0.72$). **Conclusions:** For M240 trials, results were adversely affected by the smaller targetry acoustic window (10' × 10'; data capture limited to 400 m). Wider spatial capture through targetry acoustic envelope improvements (20' × 20') afforded improved data capture for the M249 assessment (500 m), despite degraded aeroballistic characteristics and greater environmental aberration (i.e., wind drift) as ranges increased for the smaller M249 projectile (5.56 mm vs 7.62 mm for the M240). **Military Impact:** While acoustic targetry can score machine gun burst data at extended ranges, questions remain about effectiveness of these instrumentation approaches at ranges beyond 500 m when used in isolation. A combined sensors approach may be more effective for characterizing target engagement performance.

Board 46: The development of a flight sensing shirt to monitor the physiological status of military pilots and prevent unexplained physiological events

Kaj Gijsbertse [1], Charlotte Kjellander [1], Pradeep Panditha [1], Shavini Stuart [1], Erik Frijters [2], Pierre Valk [1], Boris Kingma [1]

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Purpose: Unexplained physiological events among military pilots can lead to reduced flight performance and safety. To better understand and prevent these events, reliable sensors are needed to monitor a pilot's physiological status and provide feedback. However, introducing such sensors into the environment of pilots is challenging due to adverse conditions and aviation regulations. In response, our research focuses on the development of a flight sensing shirt, a smart garment with integrated sensors for reliable and robust physiological monitoring during flights, with the aim of increasing flight performance and preventing loss of life and aircraft. **Methods:** The development of the flight sensing shirt includes the integration of printed electronics into the garment of the pilot. We have explored and evaluated various sensor solutions and sensor placement with respect to data quality and comfort. Additionally, aviation regulations related to fire-repellent and electro-magnetic signature were incorporated into the design of the flight sensing shirt. These steps were included in an iterative process leading to various prototypes. Evaluation of shirt prototypes in the human centrifuge and flight simulator "DESDEMONA" allow us to introduce operational conditions and disturbances in a controlled manner. We collected bio-signals and accelerations of the participants using strict test protocols. **Results:** The dry electrode technology employed involved the use of ultra-thin medical-grade skin-contact sensors for electrocardiogram and bio-impedance monitoring. These sensors are placed on a stretchable circuitry that is printed on thermoplastic polyurethane substrates, which in turn are seamlessly laminated onto fabrics to create a slim and comfortable fit for the garment. Analysing the collected bio-signals, we can draw parallels between the quality of the measured bio-signals and factors such as the sensor materials, measurement position, fabrics, and shirt design. Through these tests, we have gained valuable insights into two main challenges: motion

artifact of sensors, which relates to the robustness of skin-electrode contact and measurement, and the interconnection of stretchable circuitry with readout electronics. **Conclusions:** The developed flight sensing shirt was able to monitor electrocardiogram, bio-impedance and accelerations in flight conditions, however considerable technological challenges remain. The results point to technological solutions and next steps to increase the robustness of the system. Additionally, advanced algorithms are required to interpret the signals. **Military Impact:** The development of novel sensor solutions has the potential to improve flight performance and safety, as well as having significant implications in other military domains such as health monitoring and smart triage of wounded combatants.

Board 47: Markerless motion capture can detect meaningful changes in joint angles at the shoulder when wearing body armour

Ayden McCarthy [1], Jodie Wills [1], Jordan Andersen [1], Gavin K Lenton [2], Aaron J Beach [1], Tim Doyle [1]

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Purpose: Musculoskeletal injuries are one of the leading causes of financial burden, dropout, and loss of workdays in the military (Dijksma et al., 2022, BMJ Mil Health, 168(2), 136-140). Discrete kinematic measures such as range of motion (ROM) and peak angles can indicate an individual's physical capacity and injury risk (Adesida et al., 2019, Sensors, 19(7), 1597). Technology to measure and monitor these indicators may help to mitigate this problem. Markerless motion capture technology has great potential for assessing the kinematic profile of military personnel (McCarthy et al., 2023, Ergonomics, 66(3), 406-418). **Methods:** Eighteen healthy civilians (10 females and 8 males; age 30.2 ± 0.6 y; height 1.72 ± 0.11 m; body mass, 72.3 ± 14.8 kg) completed frontal (abduction / adduction) and sagittal plane (flexion/ extension) shoulder and hip movement tasks and three dynamic movement tasks (two squat variations and a drop jump) assessing the hip and knee. Participants completed three repetitions for each task under two conditions (no body armour [NBA] and 9 kg body armour [BA]). The HumanTrak measured ROM values for each movement task and condition. Averaged ROM values for NBA and BA conditions were compared using a paired sample t-test ($p \leq 0.05$). Additionally, mean differences (MD) and Cohen's d effect size (ES) were calculated. ESs were classified as trivial ($d \leq 0.2$), small ($d > 0.2$), moderate ($d > 0.5$), large ($d > 0.8$), and very large ($d > 1.3$). **Results:** The shoulder and hip frontal plane tasks were significantly different ($p \leq 0.05$). ES for the shoulder ranged from large to very large, with MD of 13.9º - 20.1º, while the hip ES was moderate, with MD of 3.35º - 3.44º. Shoulder flexion was significantly different, with a moderate ES and a MD of 8.55°. All other sagittal plane tasks demonstrated no significant differences, had trivial effect sizes, and MD of 2.56°. During the dynamic tasks, hip and knee values showed no significant differences, had trivial to moderate ES, and MD of 0.37° - 5.44°. **Conclusions:** Shoulder ROM is significantly decreased when body armour is worn. However, there are minimal differences in the ROM at the hip and knee across all observed tasks, except for the hip frontal plane tasks. Markerless motion capture is a useful tool to track meaningful changes at the shoulder to identify alterations in movement patterns, which may improve the monitoring of soldiers and lead to decreased injury risk due to early identification of movement concerns. **Military Impact:** Markerless motion capture is a time-efficient test to identify shoulder injury risk factors.

Posters 1: Human Augmentation

Tuesday 12th September, 13:15 to 14:45

Board 41: Investigating the potential of non-invasive brain stimulation to augment cognitive functioning

Yvonne M Fonken [1], Charelle Bottenheft [1], Annemarie Landman [1], Heleen Pennings [1], Annabel Horssen [1], Koen Hogenelst [1], Jan van Erp [1], Olaf Binsch [1]

[1]TNO, The Netherlands

Purpose: Brain stimulation can be used to influence neural activity by applying electrical currents, magnetic fields, or ultrasound waves to the central nervous system. Here we investigated how various non-invasive brain stimulation technologies can be used to augment cognitive functioning to benefit performance in a military context. **Methods:** We performed a literature review focusing on the potential for improving cognitive functioning of the following non-invasive brain stimulation technologies: transcranial magnetic stimulation (TMS), transcranial electrical stimulation (tES), peripheral nerve stimulation (PNS), and focused ultrasound stimulation (FUS). **Results:** We found that the most promising type of non-invasive brain stimulation for cognitive augmentation is PNS, particularly stimulation of the vagus nerve (VNS). This method shows effects on improving alertness, attention, mood, wakefulness, as well as increasing neuroplasticity to benefit learning and memory. Both tES and TMS also show promising avenues for improving cognition. However, high variability in results across studies as well as high inter-individual variability make these methods less attractive for cognition augmentation applications at this moment. FUS is a nascent technology that is not sufficiently researched yet for its potential in cognitive augmentation. However, FUS can target deep brain structures whereas TMS and tES only target superficial sites, and therefore is a technology worth monitoring. Based on this literature review we selected VNS to evaluate performance on various cognitive tasks in an experiment. In this experiment we will test alertness, learning, memory, and attention in sleep deprivation circumstances using cognitive lab tasks, as well as operational performance in a VR close quarter battle scenario. **Conclusions:** VNS seems to be the most promising non-invasive brain stimulation method for cognitive augmentation. Stimulation induced improvements of cognitive functioning have the potential to improve operational performance. Moreover, VNS application is straightforward and has minimal side effects. Compared with other non-invasive brain stimulation methods, VNS appears to show the most robust response and is easiest to implement; VNS devices are already in use for at-home treatment of cluster headaches. **Military Impact:** Non-invasive brain stimulation has the potential to improve cognitive performance, with applications in learning, attention, alertness, wakefulness, and mood. This method can be used to improve performance of human operators in a wide variety of applications within the military.

Board 42: Development of a guideline to effectively implement exoskeletons in a military context

Minke Geerts [1], Milène Catoire [1], Jikke Reinten [1], Saskia Baltrusch [1], Aijse De Vries [1]

[1]Netherlands Organisation for Applied Scientific Research, The Netherlands

Purpose: The physical workload of military personal is high due to the type of tasks performed, the duration of the tasks, and the context in which the tasks are performed. The high physical workload has a direct negative impact on operational performance in the short-term and on (sustainable) employability in the long-term. Exoskeletons are a mitigation option that could reduce the physical workload. Commercial exoskeletons are widely available, but implementation of these exoskeletons in a military context has turned out to be challenging. Therefore, the aim of this study was to develop a method to effectively implement exoskeletons in a military setting. **Methods:** A phased approach was used to develop the exoskeleton implementation method or guideline. First a broad set of target groups were visited. At these target groups a thorough workplace assessment was performed focusing on tasks, environment, context, and physical complaints. Second, based on literature and the performed workplace assessments a set of criteria was composed that should give insight into the potential of a task or workplace for the implementation of exoskeletons. Next, a target group selection was made, and the selected target groups were matched with a commercially available exoskeleton. The matched exoskeletons were then introduced and evaluated on a small scale. Parallel to all these efforts, interviews and observations were conducted at workplaces where exoskeletons were already in use. All information gathered in these different phases was converged to an exoskeleton implementation method / guideline. **Results:** The result of this study is a guideline which has been developed to implement exoskeletons in a military context. The guideline consists of four steps: (1) workplace assessment, (2) matching (of exoskeletons), (3) evaluation, and (4) implementation. Each of these steps should be taken to allow effective use of exoskeletons in a military context. **Conclusions:** In practice, the implementation and effective usage of exoskeletons in a military context appears to be challenging, although many exoskeletons are already commercially available (mainly the civil market). This guideline or method is a first step to more effectively and therefore more successfully implement available exoskeletons in the military context and thereby unlock the potential of these exoskeletons in the Armed Forces. **Military Impact:** Use of this method will make the application of exoskeletons in the military context easier and more effective, thereby positively impacting operational performance and sustainable employability of military personal.

Board 43: Cortical neural dynamics track adaptation when walking with an ankle exoskeleton

Courtney A Haynes [1], Seongmi Song [2], J Cortney Bradford [1]

[1]US DEVCOM Army Research Laboratory, USA
[2]Texas A & M University, USA

Purpose: The objective of this work was to quantify cortical neural modulations as novice users learned to cooperate with a plantarflexion-assist ankle exoskeleton. **Methods:** Twenty-two participants (15 men, 7 women) walked on a treadmill at 1.2 m·s-1 for 5 min while wearing bilateral ankle exoskeletons powered OFF and ON (PRE). Participants then completed an acclimation period of ~45 min of treadmill walking during which the exoskeleton assistance was turned off and on at random intervals. This provided participants with ~20 min practice of

walking with the assistance both on and off. Finally, participants repeated the 5 mins walking with the exoskeleton powered OFF and ON (POST). Throughout all walking trials, 128-channel electroencephalography (EEG), 10-channel electromyography (EMG), and lower body kinematics were recorded. Metrics of cortical neural activity, muscle activation, spatiotemporal gait characteristics, and sagittal plane joint kinematics were computed for the 5 min steady-state OFF and ON conditions before and after acclimation. Statistical differences were analysed using a 2 × 2 ANOVA with factors of time (PRE vs POST) and actuation (OFF vs ON). **Results:** EEG analyses identified five clusters within cortical brain regions for which alpha (8-13 Hz), beta (13-30 Hz), and theta (4-8 Hz) frequency band power were evaluated. The POST trials resulted in greater alpha band synchrony for left and right somatosensory cortices and the right sensorimotor cortex compared with PRE. Beta band power also significantly increased in the right sensorimotor cortex in POST trials compared with PRE. Gait event related power fluctuations decreased during POST trials in the theta, alpha, and beta frequency bands compared with PRE. Initially, stride length shortened, and step width increased in the ON condition, but with practice stride length increased and step width decreased. Muscle activity also decreased with practice. **Conclusions:** Increases in alpha and beta band power suggest decreased motor cortical engagement with practice. Larger step width for the ON condition suggests some perceived instability with the exoskeleton, but a reduction in step width for POST trials suggests that participants return towards a more typical gait with practice. Cortical dynamics align with more established biomechanical metrics of positive gait adaptation when learning to walk with an exoskeleton. **Military Impact:** In the interest of developing adaptive physical systems for military applications, it is critical to understand human adaptation. If we can identify physiological metrics that track soldier state and reflect the quality of the human-system interaction, these metrics can be provided as feedback to the system's controls to facilitate optimal interaction.

Board 44: 'RAS-EVAC' – the feasibility of Robotics and Autonomous Systems for military medical evacuation

Trevor Dobbins [1], Ryan Meeks [1], Donna Martin [2]

[1]Rheinmetall BAE Systems Land, UK
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Purpose: Military medical evacuation (MEDEVAC) is a complex mission that exposes personnel to dangers on the front line. Risks will multiply in a future operating environment (FOE) consisting of increasingly pervasive and lethal threats. Patient survivability is being defined by gradually decreasing timescales (e.g., The Platinum 10-minutes), which demands innovative solutions. Robotics and Autonomous Systems (RAS) are developing rapidly and driving disruptive transformations in civilian sectors. The ability of RAS to operate quickly, autonomously, and persistently suggests that there may be feasible MEDEVAC applications. **Method:** This research collated system objectives, defined the FOE, and developed operational vignettes that presented the challenges of military MEDEVAC. Alongside user personas and Human-Machine Teaming (HMT) models, this helped characterise the user, system, and task

requirements upon which to base metrics and feasibility judgments. Road-mapping activities then identified relevant technologies, informed by a cross-industry review. Assessments were made about technology maturity and timescales associated with the convergence of candidate subsystems at the platform level. RAS concepts were developed to illustrate how RAS solutions may be applied to the MEDEVAC challenges (e.g., Uncrewed Air Vehicles (UAVs) delivering supplies to the point of injury, legged (bipedal and quadrupedal) RAS conducting casualty evacuation (CASEVAC) in urban built environments, and Uncrewed Surface Vehicles (USVs) moving casualties between ship hospitals). **Results:** Research outputs included: characterising the operational context, system objectives, and high-level user, system, and task requirements produced by an end-user group that provide a framework to assess RAS feasibility for MEDEVAC applications; roadmaps identified candidate technologies and subsystems, and plotted their readiness against the epochs and stages of HMT defined by the Army RAS Strategy, and; a RAS MEDEVAC strategy that outlined if, when, and how RAS developments could be exploited, and how this is best implemented to maximise trust and acceptance. **Conclusions:** Opportunities for RAS to increase the effectiveness, responsiveness, and resilience of the MEDEVAC system are many and varied. The military must not try to do too much, too soon or risk end user scepticism, misuse, and abandonment. Instead, RAS must be introduced gradually so it can prove itself to be demonstrably capable and reliable. This must be underpinned by measurable requirements, policy, and legislation, to which compliance can be evidenced. Innovations from civilian sectors must be harnessed, and MEDEVAC scenarios should be a core use-case when developing new or procuring Commercial off the Shelf (COTS) solutions. **Military Impact:** RAS has the potential to increase the effectiveness and resilience of the MEDEVAC system, reduce bottlenecks, increase situational awareness, manage operational threats, and remove personnel from danger to increase survivability.

Thematic Sessions 5 to 8

Tuesday 12th September, 15:00 to 16:30

Thematic 5: Nutrition as a military capability to deliver human advantage: more people, more ready, more of the time

Main Room

Description

This session aims to: provide a rationale for a system-approach to military nutrition; develop a model for realising a military nutrition capability; and demonstrate the health, performance, and estimated financial-return-on-investment associated with optimal nutrition. The session will cover specific nutrient requirements of Service-entry trainees, through to personnel in high-readiness units and/or undertaking unique, arduous roles in austere environments. Promoting a military performance diet in-unit—through integrating nutrition education and food provision—to support deployed duties will be discussed. Developments in smaller, lighter, nutritionally optimised operational rations will be shared, combined with smart packaging technologies to improve utility and minimise waste. Strategically incorporating dietary supplements—as an adjunct to a food-first philosophy—will be discussed, as well as programmes embedding nutrition/dietetic practitioners delivering risk-stratified person-centred interventions. Finally, a value-chain analysis will be presented, illustrating the benefits of investing in a nutrition military capability to deliver a health and performance advantage.

Background

To optimise performance and maximise lethality in all environments, military personnel must achieve high levels of mission-preparedness to endure extended periods of physical and cognitive activity, with unpredictable rest and recovery. Nutrition and diet behaviours should provide the foundation for military health, sustaining normal (physical, cognitive, emotional) function and promoting resilience to maintain and augment human performance. However, the potential of personnel, historically, has been impaired by the quality of in-unit and operational food provision, as well as soldier, sailor, and aviator nutrition knowledge and volitional dietary behaviours. International militaries have therefore not fully maximised the value (people, strategic, and financial) that a nutrition military capability could deliver, from force generation through to frontline operational effectiveness. A system-approach to military nutrition—developing strategic feeding solutions as a military core capability—is required to fully exploit the health and performance benefits of food and nutrition to deliver human advantage.

Military Impact

This session will describe the unique needs and challenges of military feeding and nutrition, and the fundamental role that food and dietary behaviours can play in delivering human advantage. Military impact can be achieved through a systems approach—food provision, nudging environment, practitioner/service member knowledge, supporting culture, shared motivation—to a nutrition military capability for optimal physical, cognitive, and emotional performance across stages (i.e., prepare, perform, recover), in all environments. Improvements may be achieved through mitigation and/or treatment of illness/injury, augmented performance, and a more ready, more motivated, and more resilient fighting force. However, only through personnel engaging with an optimised in-unit and operational food provision can these health and performance benefits be realised. Thus, for maximum impact, militaries must shift their thinking to recognise the importance of food and nutrition as an essential military capability—contributing to a whole-system approach—that supports health, mitigates risk, and promotes performance.

Presentations

Chair: *Joanne L Fallowfield, Institute of Naval Medicine, UK*

15:00 – 15:12: Nutrition as a military capability to deliver human advantage: rationale and overarching model

Joanne L Fallowfield, Institute of Naval Medicine, UK

15:12 – 15:24: Optimising nutrition during initial military training

James P McClung, US Army Research Institute of Environmental Medicine, USA

15:24 – 15:36: Operational nutrition: technologies to reduce logistics and enable performance

Erin Gaffney-Stomberg, Combat Capabilities Development Command, USA

15:36 – 15:48: A risk-stratified, practitioner-supported model for strategic dietary supplement use in the military

Rosa Peterson, Defence Science and Technology Group, Australia

15:48 – 16:00: Nutrition for special operations forces and military members with unique demands: environment, education, food provision and practitioner-support to maintain military performance

Ashley Charlebois, Canadian Special Operations Forces command, Canada
Heïdi Boilard, Department of National Defence, Canada

16:00 – 16:12: Nutrition as a military capability: measuring impact and estimating the 'value' return

Julia Carins, Griffith University, Australia

16:12 – 16:30: Questions and discussion

Thematic 6: Human impact exposure in terrain military vehicles and onboard high-speed boats compromises combat readiness and causes severe and permanent injuries

Room 1

Description

Exposure to high-level whole-body impacts and whole-body vibration in military vehicles and onboard high-speed boats can compromise combat readiness and cause acute and permanent injuries. What impact levels and kinds of impacts are sustainable, which degrade operational readiness, and which can cause injury, is however still unknown. Research and exposure monitoring has until now focused solely on whole-body vibration. To uphold combat readiness and avoid operational restrictions, exposure to impacts needs to be understood and controlled. This session will present the state-of-the-art and the state-of-the-science, in this fast-evolving field. Topics will include: impact vs vibration; impact-induced physical fatigue; impact-induced cognitive impairment; injury mechanisms; injury rates on Special Forces boat operators; new means for measuring whole-body impact, and; an ongoing prospective NATO study to establish the real nature of human exposure to impacts and relevant limits for sustainable exposure.

Background

Injury rates seem to still increase with the increasing speeds and numbers of platforms. It is well known that exposure to high-level impacts causes acute musculoskeletal injuries. New data shows that whole-body impact also causes acute cognitive impairment, unconsciousness, and also severe traumatic brain injury. It is now crucial to fill the knowledge gap and establish what levels and what kinds of impacts are sustainable versus detrimental. This new knowledge will allow for preventing injuries during training and for optimising operations for mission success. Exposure to harmful impact magnitudes has no positive effect in training.

Military Impact

This session will cover an ongoing NATO study that will close a severe knowledge gap and give the platform operators relevant real-time information about the severity of the exposure, enabling them to optimise speed and exposure for the nature of the operation. This outcome will yield enhanced combat readiness, more efficient units and operations, fewer debilitating injuries, and reduced costs for training new operators.

Presentations

Chair: *Neil Mansfield, Nottingham Trent University, UK*

15:00 – 15:06: NATO Study RTG 344 on human impact exposure onboard high-speed boats

Steve Myers, University of Chichester, UK

15:06 – 15:16: A clinical perspective on impact-induced injuries in Special Forces

Isabelle Vallee, Canadian Armed Forces, Canada

15:16 – 15:26: Severe traumatic brain injury high-speed boat whole-body-impact

Daniel Perl, Uniformed Services University of the Health Sciences, USA

15:26 – 15:36: Exposure to impact versus vibration. What we know and what we don't know

Neil Mansfield, Nottingham Trent University, UK

15:36 – 15:43: Securing in-service personal ID integrity while surveying health and symptoms

John J Fraser, US Naval Health Research Center, USA

15:43 – 15:50: Tracking immediate effects of whole-body impacts on cognitive capacity and combat readiness.

Karen R Kelly, US Naval Health Research Center, USA

15:50 – 16:10: We can and must determine the real magnitudes and the real nature of the injurious impacts. This knowledge is critical for controlling the exposure and optimising the speed of transits

Johan Ullman, University of Gothenburg, Sweden

16:10 – 16:30: Questions and discussion

Thematic 7: A multi-institution, multi-nation approach to develop a biomarker-based, machine learning model to identify injury risk and performance in military personnel

Room 2

Description

This session will discuss how the presenters and their research teams have formed a partnership to address the research question of identifying injury risk and monitoring performance in military personnel. The two institutions involved each have specific expertise in biochemical and biomechanical biomarkers. This session will describe the mechanisms of collaboration, funding, and partnerships that have formed to enable the larger team to address this important area of interest for the militaries of two different nations. Presenters will provide results of specific studies that have been completed focussing on bone health, inertial measurement units monitoring, and predictive capabilities of biomechanical measures using a machine learning approach. The aim of the session is: 1) show how two teams, geographically dispersed, collaborate to answer a research question that would not be possible individually, and; 2) provide results from completed studies in an effort to identify injury risk and performance in military personnel.

Background

“Load monitoring” is commonplace in a sports setting, yet it is not often transferred effectively in a military context. What is considered to be “load” is ever-changing and can range from biomechanical load to a physiological stressor measured in the blood. Whatever definition of “load” is accepted, it can have a positive or negative impact on personnel. Put simply, if the load experienced creates a stimulus for adaptation and is paired with an appropriate recovery environment, the individual will respond in a positive way. Conversely, if the load is too great and/or inadequate recovery is provided, then there may be deleterious consequences—including injuries and/or performance decrements. The military provides a multi-stressor environment, and an individual may respond positively to one type of load while another responds negatively. Additionally, it is likely that all stressors interplay with each other manifesting in either an adaptation or maladaptation.

Military Impact

This research aims to provide a framework with which to quantify the load, in a broad sense, of military tasks specific to dismounted combatants. Key to this approach is the use of a machine learning model to develop a software tool, using inputs from wearable technology, that may provide relevant information to commanders about their personnel's readiness from a physical performance and injury-risk perspective. To date, the research team has developed an unsupervised clustering technique which provides thresholds from biomechanical measures to classify musculoskeletal injury risk in US Marine Corps Officer cadets (Bird et al., 2022; Front Physiol, 13, 868002). The expansion of this approach to include a range of biomarkers from wearable technology, discrete blood draws, screening measures, heart rate measures, and others, and has the potential to provide actionable information to commanders and instructors about the readiness of those under their command.

Presentations

Chair: *Tim Doyle, Macquarie University, Australia*

15:00 – 15:15: Challenges and benefits associated with multi-institutional, multi-national research collaboration

Tim Doyle, Macquarie University, Australia

15:15 – 15:30: Physiological and integrated biomarker assessment during arduous military training and operations

Bradley C Nindl, University of Pittsburgh, USA

15:30 – 15:45: Biomechanical biomarkers: What are they? How can we use them? What do they tell us?

Jodie Wills, Macquarie University, Australia

15:45 – 16:00: Biomarkers of bone adaptation and fracture risk during initial military training

Kristen J Koltun, University of Pittsburgh, USA

16:00 – 16:15: Mobile biomechanics lab: practicality of inertial measurement units to quantify in-field biomechanics

AuraLea C Fain, Macquarie University, Australia

16:15 – 16:30: Questions and discussion

Thematic 8: Recommendations for military leadership, trainers, clinicians, and researchers on preventing injuries

Room 3

Description

The prevention of musculoskeletal injuries continues to be a topic of interest for military leadership, trainers, clinicians, and researchers. Often, strategies that can effectively reduce the number of preventable injuries in the military exist; however, leadership and trainers are either not aware of these strategies or are not able to effectively implement them. Conversely, clinicians and researchers continue to study the reasons why preventable injuries happen and continue to develop new strategies for preventing injuries. Unfortunately, this research and these new strategies do not always make it to the leadership and trainers that are capable of implementing the findings. The goal of this session is share recommendations for leadership, trainers, clinicians, and researchers on how to better implement the existing evidence, best practices, and knowledge; and to create new knowledge that can be implemented in the future.

Background

Musculoskeletal injuries remain amongst the top reasons why members of the military are unable to deploy, unable to train, and medically discharged from the military. Given that many militaries are currently experiencing challenges in recruitment and retention, preventing the loss of members due to preventable musculoskeletal injuries has become a high priority for nearly all militaries. Some musculoskeletal injuries are a result of accidents during either training or sport; however, most military injuries are not accidents. Most military injuries can be considered repetitive strain injuries. These are injuries that result from an excess of cumulative loading demands being placed upon the body, without sufficient time allocated to rest and recovery between loading bouts. These injuries are generally preventable.

Military Impact

The ultimate goal of this session is to provide insights to military leaders, trainers, clinicians, and researchers on how to prevent musculoskeletal injuries more effectively in military members. By sharing recommendations that are specifically targeted to each population described, a larger number of already effective strategies at preventing injuries can be implemented, and even more effective strategies can be developed. The broad impact of this session is to prevent injuries in military members, to create a larger and more effective fighting force.

Presentations

Chair: *Thomas Karakolis, Defence Research and Development Canada, Canada*

15:00 – 15:15: Recommendations for military leadership to prevent musculoskeletal injuries in their personnel

Damien Van Tiggelen, Military Hospital Queen Astrid, Belgium

15:15 – 15:30: Recommendations for military trainers and clinicians to prevent musculoskeletal injuries in their personnel

Graham White, Defence Science and Technology Laboratory, UK

15:30 – 15:45: Recommendations for researchers to prevent musculoskeletal injuries in military personnel

Thomas Karakolis, Defence Research and Development Canada, Canada

15:45 – 16:00: Preventing overuse injuries in basic military training, theory and practice

Wes O Zimmermann, Royal Netherlands Army, The Netherlands

16:00 – 16:15: A classification model for musculoskeletal injuries risk factors in the military

Stefan Sammito, German Air Force Centre of Aerospace Medicine, Germany

16:15 – 16:30: Implementing strength and conditioning programs to generate resilience to injury

Tara Reilly, Canadian Forces Morale & Welfare Services, Canada

Oral Communication 5: Musculoskeletal Injury and Physiology

Tuesday 12th September, 17:00 to 18:00

Main Room

Chair: *Julie Greeves, Army Health and Performance Research, UK*

17:00 - 17:15: Musculoskeletal injury prevalence during Army basic training

Andrew J Roberts [1], Shaun Chapman [1], Henry Ogden [1], Alex J Rawcliffe [1]

[1]Army Recruit Health and Performance Research, UK

Purpose: Musculoskeletal injuries (MSKIs) are the single greatest health and operational threat presently faced by the recruit population, resulting in lost training time, reduced readiness, lower mood state, chronic morbidity, and permanent discharge. Our data describes the current incidence, prevalence, and nature of MSKIs across British Army basic training. **Methods:** A retrospective analysis of the Army Recruiting and Initial Training Command MSKI database was undertaken on data collected from Primary Care Rehabilitation Facilities at British Army training units between 1st April 2020 and 31st March 2022 and compared with historical data. To calculate prevalence (% recruits), data were expressed relative to the number of recruits starting each training year. **Results:** MSKIs declined over the last decade, from highs of 47% for men and 58% for women in 2013/14, to lows of 15% for men and 22% for women in 2020/21. In 2021/22, overall prevalence (23% men; 25% women) increased above pre-COVID-19 records in 2019/20 (15% men; 28% women). Overuse and trauma MSKIs accounted for 56% and 44% of all MSKIs, respectively. Lower limb injuries continue to be the primary site of MSKI, accounting for c.80% of both trauma and overuse MSKIs for both sexes. Previously (2016 to 2020), women reported a ~50% higher prevalence of MSKIs than men (23% vs 36%), though this gap has narrowed (19% vs 23%) over the last two years. The prevalence of overuse hip MSKIs in women (2.3%) compared with men (0.7%) suggests women remain at greater risk of these injuries. The knee (1.9 to 2.0%) and calf / shin (1.7 to 1.8%) were in the three most prevalent overuse injury locations for both sexes. Overuse and trauma MSKIs were most common in week 1 (11 to 17% total). Prevalence remained high in week 2 (11 to 14% total) and gradually dropped over time. **Conclusions:** Despite the MSKI prevalence between sexes reducing, women continue to be at an increased risk compared with men. Whilst it is likely COVID-19 force health protection measures influenced MSKI prevalence between 2020 and 2022, we cannot establish how or to what extent changes in MSKI prevalence are due to COVID-19 or other factors. As the highest number of injuries are experienced in the early stages of training, biopsychosocial factors at these timepoints should be investigated. **Military Impact:** Strategies to reduce MSKIs should focus on reducing the risk of lower limb overuse MSKIs, particularly those at the knee and calf / shin, early in training.

17:15 - 17:30: Helmet worn mass and implications for the neck - analysis of helmet configuration, vibration, and g-force on neck load

Phil Newman [1], Wayne Spratford [1]

[1]University of Canberra Research Institute for Sport and Exercise, Australia

Purpose: Helmets are increasingly used for carriage of vision or targeting aids and associated power supply in infantry and aviators. As a consequence, helmets may become imbalanced and require additional counterweights. This added mass has been associated with neck strain and

injury in fast jet and rotary aircrew, and infantry. Whilst modelling of neck loads due to helmet mass has occurred, predominantly this has been done in static postures. Additional vibration, G-force, or percussive force, in addition to head movements, all have implications for neck strain and injury. We report the results of dynamic neck load modelling comparing five helmet configurations in simulated force exposures during role specific tasks. **Methods:** Three of our previous studies collected three-dimensional trajectory data using a VICON Motion Capture System from six participants wearing a Gentex HGU-56/P helmet (~1.66 kg), 19 participants wearing HGU-55/P (1.21 kg), and nine participants wearing HGU-55/P with JHMCS (1.82 kg). Participants performed an array of common headchecks and postures for standardised flight scenarios. Using OpenSim software, a previously validated musculoskeletal neck model—altered to incorporate the mass of the helmet and the ability to create different force exposures—was used to derive cervical (C1, C4, and C7) kinematics and kinetics. A customised software program was then used to integrate head on trunk kinematics, helmet mass properties, and a range of force exposure profiles (vibration) to assign intervertebral neck loads in the upper (C1), mid (C4), and lower (C7) regions. The software also enabled modelling of additional helmet inertial properties, allowing Night Vision Goggles (NVG, total 2.22 kg mass) and NVG with counterweight (NVG-CW, total 2.72 kg mass) to be evaluated on the HGU-56/P helmet, making five separate simulated helmet configurations. Cumulative loads were compared between helmet configurations using one-way ANOVA and proportional loads were compared by ratio reference to the HGU-55/P. **Results:** All helmet configurations had a different effect on neck loads. Increased forward mass resulted in 2 to 22% increases in cumulative segment loading particularly at C1 and C7. The addition of vibration simulated from MH-60 Seahawk resulted in 120 to 342% increase in cumulative load. Counter weighted helmets increased mean joint moments by only 2% despite a 22% increase in total mass. **Conclusions:** Helmet design and mass distribution influences which part of the neck is most loaded and by how much. Optimisation of design needs to account for a more task representative approach of dynamic head motion to evaluate altered helmet configurations more accurately. **Military Impact:** This study proposes a novel non-invasive approach to evaluating helmet design and implications for neck strain and injury. This approach could be used for improving helmet design and safety by simulating the effects of force magnitude, force direction, mass distribution, total helmet mass, and dynamic head motion.

17:30 – 17:45: A wearable non-invasive sensor system for in-flight measurement of neck loads in rotary wing aircrew

Wayne Spratford [1], Phil Newman [1]

[1]University of Canberra Research Institute of Sport and Exercise, Australia

Purpose: The prevalence of lower-back and neck pain among helicopter pilots is significant. Research has reported rates ranging from 42 to 88% over 3- and 12-month time windows across multiple nations. These injuries have been attributed to pilot anthropometrics and physical fitness, as well as flight-related factors such as posture, vibration, mission length, helmet fit, or load. To date, the ability to quantify load or the effect of helmet inertial parameters on load during

flight in a non-invasive manner has been difficult. We report a method to estimate cervical load in aircrew using a using a validated inertial sensor system worn in-flight capable of being used across any helmet configurations or task. **Methods:** Three-dimensional trajectory data was collected using a Motion Capture System from six participants performing common head checks wearing a HGU-56/P helmet. Using OpenSim software, a validated musculoskeletal neck model, altered to incorporate the mass of the helmet and the ability to perturbate gravity in all planes was used to derive cervical (C1, C4, and C7) kinematics and kinetics. To enable a dataset that could replicate all flying environments, 27 separate perturbations were undertaken across three different helmet configurations (helmet only, with night vision goggles (NVG) and with NVG and counterweight). Data was then then collected from 2.5 h of flight, where participants were fitted with inertial sensors. A customised machine learning software program was then used to integrate head on trunk kinematics (measured in flight by sensors), helmet mass properties, and vibration to assign intervertebral neck loads based on laboratory collected data to the upper (C1), mid (C4), and lower (C7) regions during flight. **Results:** Results showed an R2 agreement between laboratory-based estimates and those in flight of 0.98, which equated to a ~1 Nm difference at each vertebra for all gravity conditions. The model was also sensitive enough to discern differences between all three helmeted conditions. **Conclusions:** The system presented here provides an opportunity for cervical neck loads to be estimated during in-situ flight with minimal interference to crew and has enough resolution to be able to detect differences between helmet configurations. **Military Impact:** This study proposes a novel non-invasive approach to monitoring neck load during flight for any helmet configuration. Results of which can then be used to prospectively monitor load, compare with injury, better understand the link between load and injury and to potentially act as an early warning system for potential injury.

17:45 – 18:00: The relative effect of headborne equipment and operational parameters on musculoskeletal burden

Michael Vignos [1], Melissa Yates [1], Griffin Holt [1], Kyle Ott [1], Connor Pyles [1], Marshall Tumperi [1], Marina Carboni [2], Jakob Hopping [3], Quang Luong [1]

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[2]US Army Combat Capabilities Development Command - Soldier Center, USA
[3]Program Executive Office Soldier, USA

Purpose: Headborne equipment (i.e., head-supported mass, HSM) may increase risk for injury and performance reductions, indicating a need for HSM requirements. HSM requirements specific to dismounted operations do not exist, primarily due to limited understanding of the effects of HSM on this population. In particular, the relative effect of HSM and operationally relevant parameters (e.g., fitness level and activity) on musculoskeletal burden is unknown, which could inform parameters to incorporate into HSM requirements. Thus, the objective of this study was to investigate the effect of HSM and operational parameters relevant to dismounted operations on musculoskeletal burden. **Methods:** A musculoskeletal model was parameterised to vary HSM properties, sex, and neck muscle strength. The ranges of HSM mass and centre of mass were based on fielded equipment. 50th percentile male and female models were created

using reported stature and neck muscle strength. Variations in neck muscle strength were created by varying the strength of the 50th percentile models between that of a 5th and 95th percentile man and woman. This parameterised model was used within a probabilistic modelling framework to create models that span a range of healthy individuals. Each model was then used to simulate walking, running, and static postures. The simulation outcome metrics were peak joint and muscle forces. Pearson's correlation coefficients (r) were computed between each input parameter and outcome metric. Muscle forces from the static simulations were input into a model of neck muscle fatigue to compute the muscles' time to exhaustion. **Results:** Preliminary results indicate that cervical spine and neck muscle forces are more strongly associated with neck posture than HSM properties. Specifically, peak forces at the skull-C1 and C7-T1 joints and peak sternocleidomastoid force were moderately correlated with neck flexion angle (r = 0.68, 0.56, and 0.64, respectively), but not HSM properties. Neck muscle exhaustion times were also most sensitive to posture with extreme neck extension angles (48°) resulting in exhaustion times as short as 13 min. **Conclusions:** Posture may have a greater impact on neck injury risk and performance than HSM properties. This suggests that both mission requirements and HSM properties may need to be considered in HSM requirements for dismounted operations. Investigation into the full tradespace of operational parameters is needed to assess which factors are most important for HSM requirements. **Military Impact:** Mission requirements may have a greater impact on musculoskeletal burden than HSM properties and, thus, should be considered when establishing guidance for headborne equipment.

Oral Communication 6: Trial Design, Methods, Conduct, and Reporting

Tuesday 12th September, 17:00 to 18:00

Room 1

Chair: *Sam D Blacker, University of Chichester, UK*

17:00 – 17:15: A change from change scores: regression to the mean in military fitness

Andrew Siddall [1]

1Defence Science and Technology Laboratory, UK

Purpose: To present and emphasise the need for adjusting for entry fitness when analysing fitness adaptation, rather than change scores alone. **Methods:** The majority of fitness change analysis in military studies compares start (pre-score) and end of training/intervention. Typically, estimates of change are made via t-test or using change scores. These approaches inherently contain information from the pre-score, and therefore are biased if the magnitude of change is related to the pre-score. In the context of physical fitness, an example would be if those of lower baseline fitness improve more than those of higher fitness. This effect is well-established in exercise physiology (greater improvements in less fit, and diminishing improvements for the very fit), but this is also highly relevant to group-based training in the military, where personnel are often trained together to a similar end-goal. Additionally, in many cases, if groups are compared (e.g., training establishments, men and women, smokers and non-smokers) these are not randomised groups, which further complicates analysis methods. **Results:** When analysing military fitness adaptation, change scores and typical comparison of means are likely unsuitable. Although a rudimentary approach for analysing this is sometimes splitting samples into quantiles of fitness, this reduces the amount of information that can be gained from analysis and has other serious flaws. At the very least, change scores should be regressed against baseline scores to assess the presence of "regression to the mean". Formally, baseline fitness should be used as a covariate (i.e., in an analysis of covariance; ANCOVA). This has the resultant effect that fitness change (as a result of training/intervention) will be different at different points on the fitness spectrum but can be estimated using the regression model. When comparing groups in the military context, the randomisation of participants assumption is often violated, and therefore it may be appropriate to allow different regression slopes for each group and examine interaction effects. **Conclusions:** Military environments, specifically group-based training practices, are highly likely to induce a form of regression to the mean in personnel improving fitness (i.e., lower fit individuals having greater improvement than those with higher fitness). Researchers in Defence should look to employ more comprehensive analysis than change scores alone to understand training effects. **Military Impact:** Defence populations are often attempting to quantify training improvement and employing more suitable analysis will enable better understanding of training needs.

15:15 – 17:30: Developing a framework for measuring soldiers and squads during a 72-h field mission

Victoria G Bode [1], Christina Caruso [1], Donald Varieur [1], John J Christopher [2], Pooja Bovard [3]; Tina Burke [4], Julie Cantelon [1]; Elizabeth Dhummakupt [5], Kari L McKenzie [1], Meghan O'Donovan [1], Kenneth Pitts [6], Kenneth Racicot [1], J Josiah Steckenrider [7], Tracey Smith [8], Jose D Villa [1], John Ramsay[1], Marianna Eddy [1], Seth Elkin-Frankston [1]

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[6]*U.S. Army Research Institute for the Behavioral and Social Sciences, USA*
[7]*U.S. Military Academy, USA*
[8]*U.S. Army Research Institute of Environmental Medicine, USA*

Purpose: Soldiers train for combat missions lasting up to 72 h without resupply. While soldiers are expected to conduct mission-critical tasks under combat conditions, the Army does not have the capability to fully capture the soldier experience in response to sustained periods of physical and mental stress. To address this challenge, we present a cross-domain framework to characterize soldier and squad performance during a 72-h field exercise. **Methods:** To develop an operationally relevant cross-domain test and evaluation framework, we aimed to embed multiple well-controlled activities into an existing situational training exercise. In partnership with an active-duty U.S. Army unit, we implemented a series of high-fidelity assessments and measures to evaluate abilities to shoot, move, communicate, navigate, and sustain operational performance throughout a situational training exercise. Baseline skills, abilities, and performance for each participant were collected over the course of a 2-week period which included Pre-Mission Baseline, Mission Execution (a routine unit-designed 72-h training exercise that began and ended with a live-fire “stress shoot”), and Post-Mission Recovery (the five days post-mission). Embedded within the operational objectives were daily assessments of socio-emotional status, cognitive performance, biomarker samples (saliva, blood), and physiological performance (e.g., strength). **Results:** Using the data collected while embedded with the unit, a six-day cross-domain test and evaluation framework was designed and successfully demonstrated with two active-duty U.S. Army Infantry Company units, including a total of 141 soldiers. Results show the utility of incorporating well-controlled, yet field attainable assessment tools into an existing 72-h training exercise. This approach enables the scientific military community to evaluate and characterise soldier performance using rigorous methodologies that are less obtrusive than laboratory assessments. **Conclusions:** This cross-domain framework demonstrates an approach to evaluate multiple domains per soldier, squad, and platoon during operational training exercises. This capability will enable decision makers to identify factors that contribute to, or degrade, performance. Future studies may use this design to better evaluate soldier performance in operationally relevant environments. **Military Impact:** Militaries require the ability to evaluate performance in a holistic and operationally relevant manner. This study can guide predictive model development, development of performance assessment measures, and readiness decision aids to optimise battlefield awareness and performance trends on key performance outcomes.

17:30 – 17:45: 10 years in the making: the development of a human factors assessment toolkit for the New Zealand Defence Force

Adam Dooley [1], Graham Fordy [2]

[1]Defence Technology Agency, New Zealand
[2]Australian Defence Apparel New Zealand

Purpose: Robust and repeatable evaluations of the equipment that soldiers, sailors, and aviators wear are essential to ensure effectiveness and safety in training and on operations. As such, the Defence Technology Agency (DTA) developed a Human Factors Assessment (HFA) toolkit which has been refined over the past decade and applied across a range of contexts. The purpose of this study is to describe the development of the toolkit from 2013 to 2023 and to provide directions for future development. **Methods:** Five representative DTA studies were selected and reviewed to elucidate how the original HFA toolkit has been developed for equipment evaluations across maritime, land, and air domains. These studies were selected to show the breadth of equipment and apparel that the toolkit has been used to assess, the major changes that have occurred, the current state of the toolkit, and areas for further refinement. **Results:** During 2013/2014, DTA developed an HFA toolkit focussed specifically on combat mobility for dismounted soldiers. The processes adopted have subsequently guided human factors evaluations of items such as civilian covert stab vests, maritime combat ensembles, and tri-service personal protective equipment. While the original toolkit was based on the Marine Corp-Load Effects Assessment Program (MC-LEAP), the toolkit has subsequently been refined away from strict adherence to a set of prescribed activities; the current state being a battery of tools from which the most appropriate can be selected. Further, each bespoke assessment battery has been developed using 'co-creation' methods, with stakeholders used as partners in the process of experimental design. This approach relies on military experts and human factors researchers collaborating to produce an assessment schedule that is both relevant to the military task and has sufficient scientific rigour to ensure exploitable insights. The current toolkit, however, remains largely mandrolic and labour intensive, which provides an opportunity for improvement. **Conclusions:** The HFA toolkit has undergone significant development since its inception. The end-state is a battery of tools that reflect the varied roles, tasks, and equipment used by NZDF personnel and a process for developing new assessments. The result is a robust and repeatable, yet dynamic and flexible HFA toolkit. To improve efficiency, further development is required to embed mobile data capture, post-processing, and visualisation applications. **Military Impact:** The assessment of military capability must reflect the roles and tasks undertaken by specific end-users. Adherence to rigid processes and a finite set of assessment activities may reduce exploitation of the insights.

17:45 – 18:00: Canadian Armed Forces Return to Duty program for ill and injured personnel: the development and implementation of a data collection trial

Julie Coulthard [1], Jennifer EC Lee [1]

[1]Department of National Defence, Canada

Purpose: The Return to Duty (RTD) programme aims to reintegrate Canadian Armed Forces members following a significant life-altering illness / injury back into the workplace once medically ready. Yet, historically, the outcome for the majority of personnel on RTD has been transition out of the military. Current limitations in available data on programme participants make it difficult to identify potential predictors of a successful outcome. To address this gap, efforts have recently moved towards developing a tool to facilitate the collection of data around the programme. **Methods:** A data collection trial was launched at an Army base which included information captured by RTD Coordinators on every participant that entered their programme between April 2018 and March 2020. Data were collected at intake, three-month intervals, and at programme exit on various demographic, military, health, and programme characteristics using a data collection tool developed for the trial. A cumulative incidence function was generated to estimate the overall marginal probability of RTD over the duration of the programme. Associations between RTD and a range of factors that were captured using the tool were also examined in a series of competing-risks regressions. **Results:** Overall, approximately 70 percent of all RTD participants returned to active duty while the remainder transitioned out of the military (n = 205). Findings indicated that the rate of RTD among participants increased at around 3 months and began to level off around 9 months, suggesting that the likelihood of RTD after this window is diminished. Lower rates of RTD were observed among participants with 15 or more years of service compared with those with less than 5 years of service in the military, and among those not yet assigned a work placement at 3 months relative to those who were. **Conclusions:** This study represents a first step in addressing the gap in our current knowledge about the characteristics of military members participating in the RTD programme and the limited number of metrics that are available to assess the programme and track participants on a continual basis. While preliminary, the findings demonstrate how the RTD data collection tool might be used to identify the factors associated with programme outcomes. **Military Impact:** This study addressed current limitations in available data on programme participants and identified potential factors associated with retention and transition programme outcomes. Continued design and implementation of a national data collection mechanism is underway, based on lesson learned from the trial.

Oral Communication 7: Physical Performance

Tuesday 12th September, 17:00 to 18:00

Room 2

Chair: *Luana Main, Deakin University, Australia*

17:00 – 17:15: Functional fitness training for the German mountain infantry

Jennifer Schlie [1], Tina Winterstein [1], Tom Brandt [1], Timo Schinköthe [1], Andrea Schittenhelm [1], Marie Heiber [1], Ingo Seidelmeier [1], Annette Schmidt [1]

[1]University of the Bundeswehr Munich, Germany

Purpose: Functional fitness training (FFT) and military fitness share many commonalities. Particularly in divisions like the mountain infantry where constantly varying physical tasks as ruck marches, climbing, skiing, and intensive combat situations must be managed while carrying heavy external loads in rough, alpine terrain under extreme weather conditions. FFT aims to prepare athletes for multifaceted challenges like weighted runs, overhead lifts, weight pulling and pushing, and technical skills like robe climbing. It can be adapted to any situation and carried out with minimal equipment, making it beneficial during field deployments. Consequently, FFT could be relevant for everyday military duties and serve to identify and address physical deficits among soldiers. The present study aimed to investigate the need for and feasibility of a FFT program in mountain infantrymen. **Methods:** Data on strength (Dr. Wolff BackCheck®, Germany), aerobic capacity during weighted uphill running (Quark CPET, COSMED, Italy), body composition (mBCA 515, Seca, Germany), and chronic pain (Questionnaire) were acquired in a mountain infantry company. Subsequently, a 15-week FFT program was designed and handed out to the supervisor with brief instructions. It comprised two weekly 60 min training sessions, supplemented by two 25 min pliability sessions. Everything could be carried out with minimal equipment and without qualified coaches. **Results:** We recruited 24 male mountain infantrymen (height: 1.82 ± 0.10 m, body mass: 82.0 ± 10.5 kg, body fat: 16.8 ± 4.3 %). Trunk flexion strength was 70.1 ± 18.9 kg and trunk extension strength was 93.5 ± 22.5 kg, resulting in a flexion / extension ratio of 0.75. Maximum aerobic capacity was 51.5 ± 5.6 mL·kg-1·min-1. 82.4 % indicated having experienced chronic pain within the past three months. In 52.9 %, the pain caused limitations in their ability to work. After completion of the 15 weeks FFT program, the application during field deployments (in total 6 weeks) was identified as a specific challenge with low workout participation. **Conclusions:** The participants indicated chronic pain that regularly restricted their working ability. Presumably, the measured trunk flexion / extension ratio—indicative of muscular imbalances—results in physical deficits and pain. **Military Impact:** To improve the unit's long-term readiness, a comprehensive training regimen needs to be integrated into daily duty, combining cardiovascular, strength, and mobility exercises with minimal effort. Future investigations should address long-term FFT interventions among different military units and help convincing military leaders of the need, applicability, and effectiveness.

17:15 – 17:30: Thermo-physiological properties of summer military uniforms with different water-repellent finishes

Joo-Young Lee [1], Seung-Hyun Kim [1], Giulio Sebastiaan Tan [2], Ga-Young Lim [1], Yoon-Jeong Back [1]

[1]Seoul National University, Korea
[2]VU University, Netherlands

Purpose: The summer combat uniform used in Korea lacks water repellency. Adding water-repellent properties to the summer uniform may increase the heat strain experienced by soldiers during summer due to the finishing process. This study aimed to evaluate the physiological and psychological strain during human wear trials of newly developed water repellent combat uniforms. **Methods:** Twelve healthy males (age: 22.4 ± 1.7 y, height: 174 ± 3 cm, body mass: 70.9 ± 10.4 kg) participated in three experimental conditions: Control (current uniform) and two different types of water-repellent finishing uniforms, namely WR-M (Water repellent finishing by Company M) and WR-T (Company T). The water repellency of the fabric was evaluated based on ISO 4920 as Grade 2 for Control, 3 for WR-M, and 4 for WR-T. Clothing insulation (Icl), measured using a thermal manikin, was 0.65, 0.67, and 0.65 clo for Control, WR-M, and WR-T, respectively. All participants wore half-sleeves, shorts, socks, combat uniform (shirt and pants), combat vest, combat boots, and combat backpack (2.6 - 2.7 kg in total clothing mass excluding combat boots and 20-kg backpack). Each trial consisted of 130 min, which included 20-min rest followed by two bouts of 40-min walking and 10-min rest. All trials were conducted in a climate chamber at an air temperature of 25°C with 50% relative humidity. **Results:** Oxygen consumption at the end of the 2nd exercise was 1,685 ± 503, 1,744 ± 236, and 1,675 ± 312 mL·min-1 without any difference among the three conditions. No significant differences were found in rectal temperature, auditory canal temperatures, heart rate, blood pressure, blood lactate concentration, total sweat rate, and the ratings of perceived exertion among the three conditions. Mean skin temperature was higher for WR-M (35.1 ± 0.6°C) and WR-T (35.0 ± 0.5°C) when compared with Control (34.6 ± 0.5°C) during the 2nd exercise ($p = 0.025$). However, no differences in mean skin temperature were found during other phases of the experiment. At the end of the 1st or 2nd exercise, oxygen consumption and clothing microclimate on the chest were greater for WR-M compared with both Control and WR-T ($p < 0.05$). In particular, during rest or exercise, participants reported feeling less hot, less humid, and less uncomfortable while wearing Control and WR-T compared with WR-M ($p < 0.05$). **Conclusions:** The physiological and psychological impacts of water-repellent combat uniforms were found to vary based on the specific differences in water-repellent finishing. Adding water-repellent finishing (WR-M) to the current combat uniform did not result in increases in soldiers' physiological strain and improved subjective evaluation. **Military Impact:** Adding water-repellent finishing to summer combat uniforms could prove to be beneficial for soldiers during outdoor training, although it is important to consider the use of advanced water-repellent finishing technologies.

17:30 – 17:45: The relationship between the U.S. Army's new combat fitness test and a simulated marksmanship performance task

Jose D Villa [1], Peioneti Lam [1], Stephanie AT Brown [1], John J Christopher [2], Linda DeSimone [1], Meghan O'Donovan [1], Clifford Hancock [1], Wade Elmore [1], Seth Elkin-Frankston [1], Victoria G Bode [1], K Blake Mitchell [1]

[1]US Army Combat Capabilities Development Command Soldier Center, USA
[2]US Army Aberdeen Test Center, USA

Purpose: The U.S. Army recently implemented a more mission-oriented fitness evaluation test

called the Army Combat Fitness Test (ACFT). The ACFT incorporates six tasks relevant to the physical demands of combat. Although the ACFT doesn't assess marksmanship ability, there may be some indirect relationships between the two, as physical fitness and strength is required for weapon handling and effective shooting. **Methods:** 155 male, active-duty Infantry U.S. Army Soldiers (age: 23.1 ± 3.4 y) completed the ACFT and a simulated marksmanship individual shooting scenario (ISS) task, comprised of static and dynamic engagements. The ISS assesses the entire marksmanship process of moving, positioning, and engaging targets. Pearson correlations were run to assess the relationship between overall ACFT scores and ISS performance measures. Besides the probability of hit measures, lower scores indicate better marksmanship performance (i.e., negative correlations with ACFT scores are associated with better performance). **Results:** There were significant correlations between ACFT score and several lethality measures, including weak correlations with dynamic probability of hit ($r(153) = 0.237$, $p < 0.01$), probability of lethal hit ($r(153) = 0.198$, $p < 0.05$), dynamic accuracy ($r(153) = -0.284$, $p < 0.001$), and static precision ($r(153) = -0.213$, $p < 0.01$). Weak, significant correlations were also found with weapon handling stability measures during pre-shot aiming, including trigger control during static ($r(153) = -0.229$, $p < 0.01$) and dynamic ($r(153) = -0.250$, $p < 0.01$) engagements, as well as static horizontal stability ($r(153) = -0.217$, $p < 0.01$) and vertical stability ($r(153) = -0.182$, $p < 0.05$). A weak, significant correlation was also found with time between target engagements ($r(153) = -0.316$, $p < 0.001$). **Conclusions:** Higher scores in the ACFT are weakly associated with an increased probability of hitting targets and making centre-of-mass hits, as well as with better shot accuracy and precision. Higher ACFT scores were also associated with better pre-shot weapon handling and quicker transitions between targets. Bigger samples and follow-on analysis with ACFT subtasks and their relationship with specific marksmanship outcomes are required to validate these relationships further. **Military Impact:** The presented analysis provides initial evidence that the ACFT can provide valuable insight on soldiers' readiness beyond only physical fitness. Although the ACFT doesn't assess marksmanship ability, there are several skills that may be beneficial in both situations, including hand-eye coordination, upper and lower body strength, balance, stability, agility, and endurance. Improvements in these areas could lead to better marksmanship ability.

17:45 – 18:00: HRV myth-busting: considerations for the measurement and interpretation of heart rate variability

Andrew Siddall [1], Katrina Hinde [1], Nicola Armstrong [1], Graham White [1]

[1]Defence Science and Technology Laboratory, UK

Purpose: To provide an overview of key practical, theoretical, and methodological considerations around the use of heart rate variability (HRV) and explore the literature behind some emerging claims pertinent to Defence. **Methods:** A non-systematic review was conducted by searching extant literature across the following purposes: (1) Summative information about the underlying physiology of HRV; (2). Reviews and meta-analyses of HRV to identify well-established correlates of HRV; (3). Published guidance and standards for HRV research, particularly methodological considerations and assessments of evidence quality; (4). Specific, emerging, or novel claims

in HRV; (5). Studies and claims which may be pertinent to Defence and Security personnel. In relation to HRV claims, reviewed evidence was categorised in terms of research quality (unclear / weak to strong) and evidence for existence of the claim itself (unclear / low to high). **Results:** The process identified the following themes: performance (task, job, or athletic), executive function, fatigue / sleep, readiness / recovery, HRV-guided training, and early identification of infection. General HRV-related considerations could be summarised into (1) HRV is non-specific and has complex physiological underpinning; (2) there is no catch-all analysis approach or HRV parameter; (3) different HRV parameters and recording durations are not interchangeable; (4) not all monitoring technologies are made equal; and (5) valid baselining of participants is vital. The following areas that were ostensibly linked to HRV were given research quality and evidence strength ratings, respectively: cognitive / executive function (moderate, medium), "resilience" (moderate, unclear), "task / job / athletic performance" (weak, low), "readiness / recovery" (unclear / weak, low), "training prescription" (strong, low), and "early warning of infection" (strong, medium / unclear). **Conclusions:** If interpreted and analysed appropriately, HRV can represent an opportunity to gain valuable information on human health and adaptation. However, HRV can fluctuate for many reasons, and is non-specific. Linking nervous system activity to specific stressors is complex, and this review presents the continual need to be critical while exploring the interaction between humans and constantly improving technologies. **Military Impact:** There is an increasing use of wearable technologies in military populations which claim to measure HRV, and associated outcomes. Overemphasising or misunderstanding the interpretation and "predictive" power of HRV can misdirect health and fitness advice, policy, and research focus. Aiding end-users and scientists to understand how, and in what contexts, to interpret HRV will help the suitable use of these technologies.

Oral Communication 8: Human Augmentation

Tuesday 12th September, 17:00 to 18:00

Room 3

Chair: *Anna Casey, Defence Science and Technology, UK*

17:00 – 17:15: An ethical, legal, and societal aspects framework for military human enhancement

Koen Hogenelst [1], Marc Steen [1], Heleen Huijgen [1]

[1]TNO, The Netherlands

Purpose: In an ongoing pursuit to enhance military competitiveness, defence ministries look for interventions and technologies that optimise human performance. This may also include human enhancement technologies that have the ability to push human performance beyond one's biological potential. As a consequence, legal, ethical, and societal objections or dilemmas may arise. To include ethical, legal, and societal aspects in an early phase of strategic decision making—in development and application of human enhancement technology—a framework is needed to aid deliberation and decision making. **Methods:** In a current defence research program, The Netherlands Organisation for Applied Scientific Research (TNO) developed a framework for the Dutch Military to increase their knowledge of human enhancement interventions and technologies, including guidance on relevant ethical, legal, and societal aspects (ELSA). **Results:** Based on literature review, legislation, agreements, and other relevant documents as well as expert opinions, important ethical (dignity, fairness, agency, responsibility), legal (necessity, legality, responsibility/accountability, autonomy/privacy), and societal aspects (societal impact, Democratic control, Alignment, Support) were identified. In February 2023, these aspects were presented to a varied group of stakeholders from both the Dutch Ministry of Defence Organisation (legal counsellors, medical doctors, health care advisory staff, special forces command, integrity office) as well as the scientific/academic community (military ethics, military law, human performance). To further stimulate the discussion of relevant ELSA aspects, a preselected human enhancement scenario or vignette was used, which entailed the use of vagal nerve stimulation to increase alertness of heavily fatigued special forces in a high-risk situation or mission. **Conclusions:** Overall, the goal of this research project is to deliver an ELSA framework to discuss military enhancement, including useful and realistic operational scenarios as well as ideas towards a governance structure. **Military Impact:** Seeking international alignment (e.g., through NATO HFM-365-T-RTG) to stimulate knowledge exchange, mutual understanding, and interoperability will benefit the military.

17:15 – 17:30: Feasibility of the Mawashi passive exoskeleton for the dismounted combatant: a pilot investigation

Greg L Carstairs [1], Richard H Molloy [1], Kurt L Mudie [1]

[1]Defence Science and Technology Group, Australia

Purpose: The Mawashi Ultralight Passive Ruggedised Integrated Soldier Exoskeleton (UPRISE) is a passive load-bearing system designed for the dismounted combatant. The aim of this study was to do a pilot investigation of the utility of the UPRISE in controlled laboratory conditions (treadmill marching), and field activities (prolonged overground march and obstacle course). **Methods:** Three male Australian Infantry soldiers (stature 177 ± 4 cm, body mass 82.7 ± 11.0

kg, age 28 ± 1 y) participated in this study. Controlled laboratory conditions involved walking on an instrumented treadmill (flat, uphill [+10%] and downhill [-10%]) at a combination of speed (2.0 km·h-1, 5.5 km·h-1, and 7.5 km·h-1) and load configurations (23 kg Fighting Order [FO] and 41 kg Marching Order [MO]), with and without the UPRISE. Field trials included a 15 km overground march at 5.5 km·h-1 in MO and the Load Effects Assessment Program obstacle course in FO. Mean oxygen consumption (VO_2), mean heart rate (HR), rating of perceived exertion, and in-shoe force measurements were measured during the marches. Pacing of the march was measured via GPS and the obstacle course was instrumented with an optical timing system. **Results:** During the lab trials, participants demonstrated a load offset wearing the UPRISE of 5 to 15 kg (participants 1 and 2) in MO, and 5 to 13 kg (participant 3) in FO. Participants did not perceive the treadmill trials to require more effort when wearing the UPRISE, participants 1 and 3 demonstrated an increase in VO_2 and HR from 10 - 32% and 5 - 15% across all conditions, respectively. Participant 2 demonstrated an 11% reduction in VO_2 during downhill walking in the MO configuration and no change across all other conditions. Participants only completed 6.1 km, 10 km, and 10 km of the 15 km march wearing the UPRISE, with increased times of 27:38 mins, 40:22 mins, and 59:45 mins compared to conditions without the UPRISE, respectively. However, there were frequent stoppages to resolve human-system integration issues and, when excluded, increases in marching time were reduced to 7:13 mins, 1:33 mins and 16:29 mins. Obstacle course completion time increased on average by 28% when wearing the UPRISE. **Conclusions:** The UPRISE did not demonstrate the ability to assist the dismounted combatant in this pilot investigation. Overall, the load offset wearing the UPRISE did not outweigh the penalty of increased energy consumption, restrictions in movement, increased time navigating through an urban environment and difficulty traversing across multiple slopes, uneven terrains and obstacles. **Military Impact:** The UPRISE at the tested technology and integration maturity level did not demonstrate an advantage to the dismounted combatant.

17:30 – 17:45: Biomechanical adaptations to novel ankle exoskeleton use

Courtney A Haynes [1], Seongmi Song [2], J Cortney Bradford [1]

[1]US ARMY DEVCOM Army Research Laboratory, USA
[2]Texas A&M University, USA

Purpose: The objective of this work was to quantify biomechanical changes occurring as novice users learned to use an ankle exoskeleton providing plantarflexion assistance. The aim was to identify candidate physiological metrics that may be used to monitor or improve human-system interaction. **Methods:** Twenty-two participants (15 men, 7 women) performed treadmill walking at 1.2 m·s-1 while wearing bilateral ankle exoskeletons. Initial exposure (PRE) conditions consisted of 5 min of walking for each of the powered OFF and ON conditions. An acclimation period was then completed in which the power state of the exoskeleton alternated between OFF and ON roughly 30 times over the course of approximately 45 min. Following this acclimation period, participants again completed 5 min of steady-state walking (POST) with the exoskeleton powered OFF and ON. Instrumentation included 128-channel electroencephalography (EEG), 10-channel electromyography (EMG), and lower body kinematics which were recorded synchronously for

all trials (Song et al., 2023, Research Square, https://doi.org/10.21203/rs.3.rs-2675191/v1). The study presented measures of muscle activation, spatiotemporal gait characteristics, and sagittal plane joint kinematics computed for the PRE and POST trials. For each metric, a 2 × 2 ANOVA (Time = PRE / POST, Actuation = ON / OFF) was used to identify statistical differences with an alpha of 0.05. **Results:** Step width was significantly greater (0.80 cm) for ON than OFF, but also greater (0.70 cm) for PRE compared with POST trials. Joint angles were primarily affected by time, but ankle dorsiflexion and hip flexion were reduced (−1.2 deg and −0.8 deg, respectively) and knee range of motion increased (1.7 deg) for ON compared with OFF conditions. Muscle synergy patterns were unaffected by the exoskeleton. Unitless area under the curve revealed reduced soleus (−2.2), lateral gastrocnemius (−2.1), and biceps femoris (−1.2) activation for ON compared with OFF. Initial ON exposure resulted in increased (4.3%) synergistic activation of rectus femoris and tibialis anterior muscles, but all muscles showed reduced activation for POST compared with PRE trials. **Conclusions:** Larger initial step width and synergistic activation of tibialis and rectus femoris muscles suggest an initial maladaptive response to the plantarflexion assistance. With practice, however, step width trended back towards baseline, and activation of all muscles were reduced by the conclusion of the paradigm resulting in small but significant changes to joint kinematics. **Military Impact:** Understanding human adaptation to intelligent physical agents can aid in developing mutually adaptive physical systems for military use. Incorporating real-time physiological or biomechanical feedback from metrics that track soldier state could help optimize and customise human-system performance.

17:45 – 18:00: The physiological and biomechanical effects of a full-body passive exoskeleton on military load carriage

Cheryl Lim [1], Pui Wah Kong [2], Ang Hong Koh [2], Mavis Ho [2], Shahril Iskandar Muhd Nur [2]

[1]Singapore Armed Forces, Singapore
[2]Nanyang Technological University, Singapore

Purpose: Prolonged load carriage during military training and operations imposes physiological and physical stresses on the human body, increasing fatigue and the risk of injuries. Wearable exoskeletons have been designed to offload weight from the human, potentially reducing injury risk and enhancing physical performance. This study evaluated the physiological and biomechanical effects of a full-body adjustable passive exoskeleton designed to partially offload shoulder-borne pack loads to the ground. **Methods:** Eight Singapore Armed Forces servicemen (age, 32 ± 6 y; height, 170 ± 6 cm; body mass, 70 ± 4 kg) were fitted with the exoskeleton (weighing approximately 8 kg) based on their anthropometry and underwent a familiarisation and conditioning period (approximately 10 h of exoskeleton use). They then performed a series of trials with and without the exoskeleton. During 10 s quiet standing with different loads (0 to 55 kg), in-shoe vertical ground reaction forces (vGRF) were measured using Novel loadsol®. Participants also performed 10 min treadmill walking with different loads (25 kg, 35 kg) and gradients (flat, 10° inclined, 10° declined), during which in-shoe vGRF and treadmill 3D GRF were measured. Additionally, oxygen consumption was recorded for five participants during treadmill walking. Results were analysed using repeated measures ANOVA.

Results: During quiet standing, there was a significant main effect of exoskeleton ($p = 0.029$) on in-shoe vGRF, with 18 to 44% of pack weight offloaded. However, notable inter-individual variations were observed, with no clear trend in augmentation. During treadmill walking on flat surface, exoskeleton use resulted in higher peak in-shoe vGRF across both load conditions ($p = 0.006$). On inclined surface, Tukey's post-hoc test showed lower vGRF with 35 kg load and no difference for the 25 kg condition. No differences were found for walking on declined surface ($p = 0.072$). Exoskeleton use significantly increased oxygen consumption on flat ($p < 0.001$) and inclined ($p = 0.048$) surfaces, with no difference detected for declined surface ($p = 0.127$). **Conclusions:** The passive exoskeleton evaluated did not present clear load transference benefits for the user but imposed a penalty on oxygen consumption. This physiological cost is likely attributable in part to the added exoskeleton weight and could outweigh other potential benefits. **Military Impact:** While exoskeleton technology matures, continued emphasis should be placed on efforts to reduce the load burden of our dismounted operators while providing adequate conditioning to minimise injury risk and optimise performance.

Thematic Sessions 9 to 11

Tuesday 12th September, 18:15 to 19:45

Thematic 9: Managing physical health and performance in the military: enablers and impediments

Main Room

Description

Considerable research has been conducted over recent decades examining musculoskeletal injury, training stress, and physical fitness in Defence settings. Collectively, this research has involved considerable resource, yet it may be argued that there has been insufficient return on this investment. This is not a judgement on the quality of the research, rather a reflection of the complexity associated with conducting research in military settings and the difficulty in translating the findings into practical applications for health professionals and military leadership. Therefore, the aim of this session is to address various enablers and impediments associated with health and performance management of military personnel. A variety of lived experiences, observations, and learnings will be shared to help guide university researchers, Defence scientists, and military stakeholders in undertaking translational research that achieves real-world impact.

Background

Irrespective of the context, physical and physiological capacity underpins the occupational performance of military personnel. This is well-established in the land domain, where load carriage and manual material handling is ubiquitous, often undertaken in multi-stressor environments involving compromised sleep and nutrition. However, physical and physiological health is equally important in the air and maritime domains where physical demands may often be lower, but high cognitive workloads, psychological stressors, shift work, and austere environments require physiological resilience to maintain health and sustain occupational performance. Therefore, it is imperative for military organisation to maintain the physical and physiological capacity of its workforce to maintain operational capability. However, high rates of musculoskeletal injuries and medical downgrades result in considerable reductions in deployable capability for many countries. This is further compounded by increasing pressures to meet recruiting targets and maintaining an active-duty workforce.

Military Impact

Many military organisations are facing recruiting pressures, attributable at least in part to declining population health. These recruiting pressures are exacerbated by the requirement to sustain existing capabilities whilst growing emerging capabilities (e.g., cyber). Within the active-duty workforce, musculoskeletal injury and mental health are associated with considerable medical downgrades (i.e., non-deployable personnel). There is the potential for research and initiatives to support military organisations in meeting these challenges, however, we need to be more cognisant of the potential enablers and impediments. It is proposed that a systems-level approach to managing the physical health and performance of military personnel is required to achieve this aim and support data-informed decision making. Improved through career management of physical health and performance will yield many benefits including a more capable and deployable workforce, reductions in the burden on the health system, and improvements in a member's health during and after their military career.

Presentations

Chair: *Jace Drain, Defence Science and Technology, Australia*

18:15 – 18:27: Embracing technology to support physical training delivery and command decision making

Daryl Allard, Canadian Forces, Canada [12 minutes]

18:27 – 18:39: Musculoskeletal complaint epidemiology in Australian Special Operation Forces trainees

Joanne Stannard, Edith Cowan University, Australia
Kurt L Mudie, Defence Science and Technology, Australia

18:39 – 18:51: Data analytics to inform the physical health and performance of military personnel

Andrew Siddall, Defence Science and Technology Laboratory, UK

18:51 – 19:03: Health and performance research translation and implementation

Emma Williams, Australian Army, Australia

19:03 – 19:15: Policy and public relations – lessons learned

Michael S McGurk, US Army, USA

19:15 – 19:27: Managing the health and performance ecosystem to maximise organisational capability

Jace Drain, Defence Science and Technology, Australia

19:27 – 19:45: Questions and discussion

Thematic 10: Cold operational readiness: from science to practice

Room 1

Description

Cold weather operations are logistically difficult to orchestrate and extremely challenging for soldiers. Decades of research clearly indicate that humans are not only extremely vulnerable to cold, but that individual responses are also highly variable. In this context, it may be necessary to develop personalised strategies to sustain soldier's performance and ensure overall mission success in the cold. Systematic cold weather training is essential to allow soldiers to best prepare to operate during, and recover from, cold weather operations. The purpose of this thematic session is to highlight key aspects of cold weather training, including: (1) human responses to cold; (2) nutrition; (3) sleep, and; (4) protective equipment requirements. Bringing science to practice to improve training principles, can facilitate soldiers performing safely and adequately in the cold.

Background

Cold weather training and operations provide a great opportunity to acquire survival and tactical skills necessary to operate in such environments. However, research has consistently shown that these training and operational opportunities are often associated with reductions in cognitive and physical performance as well as with a high risk of developing cold weather injuries (i.e., non-freezing and freezing cold injuries, and hypothermia). Inability to sustain performance and increased risk of cold weather injuries can be primarily attributed to: 1) interindividual variations; 2) previous cold weather injuries; 3) inadequate protective equipment and/or improper use of this equipment; 4) high energy deficits, and; 5) sleep deprivation. While some of these factors are inherent to winter warfare, a better understanding of soldier responses to training practices, as well as their environment, can lead to optimisation of the capacity for soldiers to master cold weather warfare.

Military Impact

Cold weather training allows soldiers to prepare for operations in cold harsh environments. Decreases in physical, psychological, and thermoregulatory performance have been reported following such training, which influences operational ability and increases the overall risk of injuries. Closing the gap between research and training in the field allows for a better coordination of efforts to better prepare soldiers, including updating training strategies. When optimising the planning of field training exercises or operational missions, it is important to understand the soldier's physical and cognitive performance capacity, to understand their capacity to cope and recover during and following the exercise or mission. Even though the body is fully recovered in terms of body composition or hormonal concentrations, physical or cognitive performance can still be unrecovered. In cases in which this trajectory is overlooked, symptoms of overtraining and risk of injury may increase, decreasing operational readiness.

Presentations

Chair: *Tommi Ojanen, Finnish Defence Research Agency, Finland*

18:15 – 18:30: Physiological responses during cold weather training in the field

Tommi Ojanen, Finnish Defence Research Agency, Finland

18:30 – 18:45: Cold acclimation: optimisation of cold tolerance

Francois Haman, University of Ottawa, Canada

18:45 – 19:00: Prediction of finger skin temperature during cold exposure by an individualised heat balance model

Koen van der Sanden, TNO, Netherlands

19:00 – 19:15: Sleep health and human performance during cold weather training

Guido Simonelli, University of Montreal, Canada

19:15 – 19:30: Impact of low energy availability during cold weather military operations

Lee Margolis, US Army Research Institute of Environmental Medicine, USA

19:30 – 19:45: Questions and discussion

Thematic 11: Maximising the health and performance of women in ground close combat roles

Room 2

Description

In the last decade, many nations have opened military ground close combat roles to women. The objective to close with and kill the enemy requires the fittest of soldiers to operate in austere environments carrying very heavy loads. Servicewomen are challenged more than ever to fight and survive in the heat and cold, with limited food, and restricted sleep, whilst meeting new employment standards of strength, endurance, and anaerobic power. Evidence-based training and nutritional interventions to prevent ill-health and optimise performance have not considered physical and endocrinological characteristics of women. This Thematic Session will synthesise key findings from research undertaken in response to the UK's decision to fully integrate women in the military. Speakers from the British Army will present original findings that contribute to 'closing' the gender gap in exercise science and highlight recommendations to optimise health and performance of women engaged in arduous training.

Background

The British Army was asked by Ministers in 2014 to provide advice on the risks of opening ground close combat (GCC) roles to women, which were previously closed on the basis of operational effectiveness. The British Army recognised the gender data gap in the literature on key areas affecting military performance and recommended that a comprehensive and coherent program of research on the health and performance needs of women was prioritised to inform and support employment policies. A substantial body of research was undertaken to establish gender-free physical employment standards for GCC roles, understand the health and performance risks of servicewomen, and identify strategies to mitigate risk. This research started in 2015, involving cross government and academic collaboration, and will report in 2023. The proposed session will showcase headlines from this state-of-art research program.

Military Impact

Emerging evidence will improve policies and practices to maximise the health and performance of servicewomen through career and promote their equity of employment in defence.

Presentations

Chair: *Karl Friedl, US Army Research Institute of Environmental Medicine, USA*

Speakers and Titles:

18:15 – 18:20: Introduction

Karl Friedl, US Army Research Institute of Environmental Medicine, USA

18:20 – 18:35: Overview: women in ground close combat roles; closing the gender data gap

Julie P Greeves, Army Health and Performance Research, UK

18:35 – 18:50: EmployHER: development and implementation of gender-free role related fitness tests

Julie Draper, British Army, UK

18:50 – 19:10: TrainHER: physical training strategies to maximise female performance

Thomas J O'Leary, Army Health and Performance Research, UK

19:10 – 19:30: ProtectHER: nutrient support to sustain health and performance through career

Charlotte V Coombs, Army Health and Performance Research, UK

19:30 – 19:45: Questions and discussion

Oral Communication 9: Nutrition and Metabolism

Tuesday 12th September, 18:15 to 19:45

Room 3

Chair: *William R Conkright, US Army, USA*

18:15 – 18:30: Effects of a gut microbiota-targeted nutrition intervention on intestinal permeability and illness symptoms in Soldiers following rapid ascent to simulated high altitude: a double-blind, randomised, crossover study

J Philip Karl [1], Heather S Fagnant [1], Patrick N Radcliffe [1], Marques A Wilson [1], Anthony J Karis [1], Harris R Lieberman [1], Grace E Giles [2]

[1]U.S Army Research Institute of Environmental Medicine, USA
[2]U.S. Army Combat Capabilities Development Command Soldier Center, USA

Purpose: Increased intestinal permeability (IP) may contribute to illness and performance decrements experienced upon rapid ascent to very high terrestrial altitude (> 4000 m). Fermentable fibres and polyphenols can reduce IP through interactions with the gut microbiota, but whether this benefit occurs at altitude is unknown. This study aimed to determine the effects of dietary supplementation with a blend of fermentable fibre and polyphenol sources on IP and gastrointestinal and illness symptoms following rapid ascent to simulated high altitude. **Methods:** Thirty-three unacclimatised Soldiers (21 ± 3 y) participated in a randomised, double-blind, crossover study consisting of three 2-week study phases separated by ≥ 1 week. Snack bars providing 15 to 30 g·d-1 fermentable fibres (oligofructose-enriched inulin, galactooligosaccharide, high amylose corn starch) and 1 to 2 g gallic acid equivalents/d total phenolics from cocoa seed, green tea leaf, cranberry, and blueberry (FP) or placebo (PL; maltodextrin substituted for fermentable fibres and polyphenol sources) were consumed daily during each phase. FP and PL products were matched for total carbohydrate, fat, and protein content. During the final 2 d of each phase participants resided for ~ 36 h in a hypobaric chamber simulating low altitude (LA; 500 m) or high altitude (HA; 4300 m) to create three conditions: PL+LA, PL+HA, FP+HA. During chamber residence, IP was measured by 0 – 5 h and 5 – 24 h urinary sucralose and erythritol excretion and circulating LPS-binding protein (LBP), and acute mountain sickness (AMS) was measured by Environmental Symptoms Questionnaire. Gastrointestinal symptoms were measured throughout each phase using a modified Gastrointestinal Quality of Life Index (GIQLI). Linear mixed models examined between-condition differences in the 26 and 13 participants who completed ≥ 1 (intention-to-treat cohort) and all 3 (complete case cohort, CC) phases, respectively. **Results:** During HA, 0 – 5 h sucralose and erythritol excretion and their ratio (CC analysis only) were 15 – 30% lower in FP versus PL ($p < 0.05$), while 5 – 24 h measures and LBP did not differ. AMS scores were increased at HA and did not differ between FP+HA and PL+HA. GIQLI scores did not differ between conditions prior to chamber residence but were ~ 12% worse in FP versus both PL conditions during chamber residence ($p < 0.05$). **Conclusions:** Findings suggest this gut microbiota-targeted fermentable fibre and polyphenolrich intervention may reduce intestinal permeability within the small and proximal large intestine while marginally increasing gastrointestinal symptoms following rapid ascent to HA. **Military Impact:** Gut microbiota-targeted nutrition interventions may comprise a potential strategy for improving physiologic responses that contribute to performance decrements caused by environmental stressors such as high altitude, but side effects require consideration and

effects on performance metrics need to be demonstrated. Disclaimer: Authors' views are not official U.S. Army, DoD or Government policy.

18:30 – 18:45: Pre-sleep protein supplementation does not improve performance, body composition, or recovery in British Army recruits

Shaun Chapman [1], Alex J Rawcliffe [1], Andrew J Roberts [1], Henry Ogden [1], Rachel Izard [2], Lee Smith [3], Justin Roberts [3]

[1]*Army Recruiting and Initial Training Command, UK*
[2]*Defence Science and Technology, UK*
[3]*Anglia Ruskin University, UK*

Purpose: Dietary protein intake is crucial for optimising training adaptations including muscular strength, which is a key aim during British Army basic training (BT). Recruits fail to meet the recommended daily protein intake of 1.5 to 2.0 $g \cdot kg^{-1} \cdot d^{-1}$, with negligible amounts of protein consumed in the evening. This study aimed to assess whether an additional daily bolus of protein prior to sleep influenced subsequent performance adaptations, body composition, and markers of recovery in British Army recruits. **Methods:** 99 men and 23 women at the Army Training Centre, Pirbright were randomised to a dietary control (CON), carbohydrate placebo (PLA), moderate protein (20 g, PRO20), or high protein (60 g, PRO60) supplement group. Physical performance (mid-thigh pull, medicine ball throw, 2 km run, maximal push-up, and maximal vertical jump) and body composition were assessed at the start and end of training (weeks 1 and 12). All other measures (dietary intake [self-report food diary], energy expenditure [Actigraphy], salivary hormones, nitrogen balance [24-h urine collection] and self-report muscle soreness, perceived exertion, mood, and fatigue were assessed at the start (weeks 1, 2), middle (week 6), and end (week 12) of BT. Mixed-model analyses of covariance with adjusted Bonferroni post hoc tests were used to examine changes in performance, body composition, and recovery markers between supplement groups. **Results:** Protein supplementation increased daily protein intake in both the PRO60 (2.16 ± 0.50 $g \cdot kg^{-1} \cdot d^{-1}$) and PRO20 (1.71 ± 0.48 $g \cdot kg^{-1} \cdot d^{-1}$) compared with CON (1.17 ± 0.24 $g \cdot kg^{-1} \cdot d^{-1}$) and PLA (1.31 ± 0.29 $g \cdot kg^{-1} \cdot d^{-1}$) ($p < 0.001$). Nitrogen balance was greater in PRO60 compared with CON (10.7 ± 3.5 $g \cdot d^{-1}$ *vs* 2.6 ± 2.7 $g \cdot d^{-1}$, $p < 0.001$), PLA (2.3 ± 3.8 $g \cdot d^{-1}$, $p < 0.001$), and PRO20 (2.9 ± 4.6 $g \cdot d^{-1}$, $p < 0.001$) at week 12. No significant impact of protein supplementation on changes in mid-thigh pull (CON = 7 ± 19%, PLA = 7 ± 19%, PRO20 = 0 ± 16%, PRO60 = 4 ± 14%) or any other performance test ($p > 0.05$) was observed. Changes in fat-free mass were similar between groups (CON = 4 ± 3%, PLA = 4 ± 4%, PRO20 = 3 ± 3%, PRO60 = 5 ± 4%, $p = 0.959$). There was no impact of protein supplementation on recovery markers ($p > 0.05$). **Conclusions:** There was no impact of protein supplementation on performance, body composition or recovery, possibly due to a suboptimal training stimulus. There was high inter-participant variability, suggesting an individualised use of protein supplementation should be explored. **Military Impact:** Protein supplementation beyond intakes recommended for physically active populations to support performance, body composition and recovery adaptations in British Army recruits does not appear to be warranted.

18:45 – 19:00: Evaluation of obese body mass as a risk factor for higher inflammatory biomarkers and worse outcomes from mild traumatic brain injury

Shawn Eagle [1], William R Conkright [2], Ava Puccio [1], Lindsay Nelson [3], Michael McCrea [3], Joseph Giacino [4], Ramon Diaz-Arrastia [5], Sonia Jain [6], Xiaoying Sun [6], Geoff Manley [7], David Okonkwo [1]

[1]University of Pittsburgh, USA
[2]US Army, USA
[3]Medical College of Wisconsin, USA
[4]Harvard Medical School, USA
[5]University of Pennsylvania, USA
[6]University of California San Diego, USA
[7]University of California San-Francisco, USA

Purpose: Mild traumatic brain injury (mTBI) and obesity are highly prevalent in the US military; both are associated with inflammation, which can worsen outcomes. The purpose of this study was to assess the role of obesity on inflammatory blood biomarkers, symptoms, health-related quality of life, and functional outcomes in persons who presented to a level 1 hospital emergency department with an mTBI. **Methods:** Participants (n = 770) enrolled in Transforming Research and Clinical Knowledge in Traumatic Brain Injury (TRACK-TBI) with a Glasgow Coma Score = 13-15 and obese body mass (BMI > 30.0 kg·m-2) or normal mass (BMI = 18.5 – 24.9 kg·m-2). Participants completed the Rivermead Post-Concussion Symptoms Questionnaire (RPQ) and provided blood samples within 24 hours of injury (D1) and were followed up at two weeks (W2), three months (M3), six months (M6), and twelve months (M12) post-injury. Concentrations of high-sensitivity c-reactive protein (hsCRP), interleukin-6 (IL-6), interleukin-10 (IL-10), and tumour necrosis factor alpha (TNFα) were obtained. Linear mixed effects models were used to compare biomarkers (in log-scale) at D1, W2, and M6 and RPQ at W2, M3, M6, and M12 between groups. **Results:** After adjusting for age and gender, obese participants had higher concentrations of hsCRP (log scale) at D1 (mean difference [95% CI] = 0.65 [0.44, 0.87], $p < 0.001$), W2 (0.99 [0.74, 1.25], $p < 0.001$), M6 (1.08 [0.79, 1.37], $p < 0.001$) compared with healthy mass participants. Obese participants had higher concentrations of IL6 (log scale) at W2 (0.37 [0.11, 0.64], $p = 0.006$) and M6 (0.42 [0.12, 0.72], $p = 0.006$). After adjusting for age, gender, race, years of education, psychiatric history, and prior TBI, obese participants had higher RPQ symptoms at M6 (2.79 [0.44, 5.14], $p = 0.02$) and M12 (2.37 [0.01, 4.73], $p = 0.049$). **Conclusions:** Pre-injury obesity may be a risk factor for higher mTBI symptomatology at 6- and 12-months and higher concentrations of inflammatory markers up to 6 months post-injury. **Military Impact:** Obese body mass and mTBI rates continue to rise in the US military. Based on current trends, >50% of the public and US military will be obese by 2030, which may complicate and prolong recovery from mTBI due to higher baseline inflammation. Obesity and mTBI are associated with sequelae whose phenotypes often overlap (e.g., post-traumatic stress disorder, depression, anxiety, migraines, and sleep disruption). Determining a biologic signature of mTBI response in the obese service member will be critical for mTBI management in the immediate future.

19:00 – 19:15: Essential amino acid-enriched whey protein rescues post-exercise muscle protein synthesis during energy deficit

Jess Gwin [1], David Church [2], Jillian Allen [1], Marques A Wilson [1], Nancy Murphy [1], Christopher Carrigan [1], Alyssa Varanoske [3], Lee Margolis [1], Robert Wolfe [2], Arny Ferrando [2], Stefan Pasiakos [1]

[1]U.S. Army Research Institute of Environmental Medicine, USA
[2]University of Arkansas for Medical Sciences, USA
[3]Oak Ridge Institute of Science and Education, USA

Purpose: Military personnel are frequently exposed to unavoidable energy deficits (energy requirements exceed energy intake) due to increased physical activity coupled with inadequate energy intake during training and operations. Energy deficits decrease muscle protein synthesis (MPS), which may result from greater whole-body essential amino acid (EAA) requirements and reliance on EAA to support energy demand. Whether this energy deficit-induced anabolic resistance may be overcome through the provision of acute supplemental energy or if increased EAA are needed to stimulate MPS is unknown. Therefore, we tested the effects of supplemental energy in the forms of EAA or carbohydrate, combined with an EAA-enriched whey protein, on post-exercise MPS and whole-body protein turnover. **Methods:** 17 adults (mean ± SD; age: 26 ± 6 y, BMI: 25 ± 3 kg·m2) completed a randomised, double-blind parallel study including two 5 d energy conditions (BAL, energy balance; DEF, 30 ± 3% energy requirements) separated by ≥ 7 d. Volunteers consumed either an EAA-enriched whey beverage with added EAA (+EAA; 304 kcal, 56 g protein, 48 g EAA, 17 g carbohydrate, 2 g fat, n = 8) or with added carbohydrate (+CHO; 311 kcal, 34 g protein, 24 g EAA, 40 g carbohydrate, 2 g fat, n = 9) immediately after 60 min of load carriage (59 ± 4% VO_2peak) and alternating step ups (9 sets × 16 repetitions). Post-exercise MPS and whole-body protein synthesis (PS), breakdown (PB), and net balance (NET; PS-PB) were estimated using 2H5-phenylalanine and 2H2-tyrosine kinetics. **Results:** Within treatments, MPS (%·h-1) was similar across conditions (+EAA: BAL, 0.073 ± 0.02 vs DEF, 0.083 ± 0.02, p = 0.359 and +CHO: BAL, 0.081 ± 0.03 vs DEF, 0.059 ± 0.01; p = 0.056). Between treatments, MPS did not differ during BAL (p = 0.45), but was higher in +EAA than +CHO (p = 0.015) during DEF. Under both conditions, PS (g protein per 240 mins) was higher in +EAA (BAL, 117.9 ± 16.5; DEF, 110.3 ± 14.8) than +CHO (BAL, 81.6 ± 8.0; DEF, 83.8 ± 5.9; both p < 0.001). Regardless of condition, PB (g protein per 240 mins) was less in +EAA (8.0 ± 16.5) than +CHO (37.8 ± 7.6; p < 0.001). Regardless of condition, NET (g protein per 40 mins) was higher in +EAA (106.1 ± 6.3) than +CHO (44.8 ± 8.5, p < 0.001). **Conclusions:** These data suggest that enhancing an EAA-enriched whey protein with supplemental energy in the form of EAA, and not carbohydrate, counters anabolic resistance and maintains postprandial MPS during energy deficit. **Military Impact:** An EAAenriched whey protein beverage formulated with more EAA compared to carbohydrate represents an optimized eat-on-the-go supplemental food option for promoting anabolism in military personnel during periods of energy deficit. Disclaimer: Not official Army / DoD policy.

19:15 – 19:30: Impact of a 24-h exposure to hot and cold environments on appetite, food preferences, and energy intake

Keyne Charlot [1], Maxime Coca [1], Louis Besançon [2], Mégane Erblang [3], Stéphanie Bourdon [1], Arnaud Gruel [1], Benoît Lepetit [1], Vincent Beauchamps [1], Blandine Tavard [4], Fabien Sauvet [1], Pierre-Emmanuel Tardo-Dino [1], Alexandra Malgoyre [1], Cyprien Bourrilhon [1]

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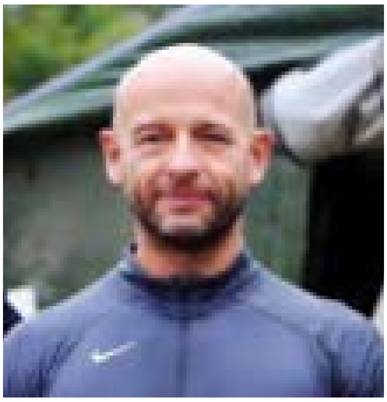
[4]Service du commissariat des armées, France

Purpose: It is suggested that exposure to hot and cold environments may modify appetite and spontaneous energy intake (EI) and somewhat aggravate the risk of energy deficit that is almost always observed during military training. The aim of this study was therefore to investigate the effects of 24-h cold (16°C) and hot (32°C) exposures on food intake and on the potential underlying mechanisms—subjective hunger and food preferences—compared with a hermos-neutral condition (24°C). **Methods:** Twenty-four healthy, young, and active male participants all wearing the same clothing (Clo = 1) completed three 24-h sessions in a laboratory designed like an apartment. Three meals (dinner at 7:00 pm, breakfast at 8:00 am and lunch at 12:30 pm) composed of three or four dishes were served to assess EI. Leeds Food Preference Questionnaires were used before each meal to assess fatness (high-fat / low-fat), taste (sweet / savory), texture (fluid / solid) and temperature (cold / hot). Finally, subjective appetite was regularly assessed. **Results:** Contrary to the main hypothesis, EI during 24 h was not modified (14.36 ± 2.60, 14.18 ± 2.90, and 14.93 ± 2.97 MJ for 16, 24, and 32°C, respectively). Accordingly, appetite ($p = 0.55$), meal duration ($p = 0.54$), and food palatability ($p > 0.40$) were also not altered. Interestingly, preferences for high-fat, sweet, and cold foods / drinks were the highest during the 32°C. Intra-meal analysis revealed some differences between sessions (more food was consumed in the hot meal at dinner at 16 than 24°C, $p = 0.005$; more orange juice was consumed at breakfast at 32 than 24°C, $p = 0.048$) that may be concordant with these modifications of preferences. **Conclusions:** 24-h heat and cold exposure did not modify the appetitive response in well-controlled conditions, suggesting minimal risk of thermal-related energy deficit. The fact that the test meals were composed of several items with different characteristics (mainly cold or hot) may have allowed participants to select items they preferred. **Military Impact:** The risk of energy deficit in a hot or a cold environment (within the study's thermal conditions) seems limited if different kind of foods (mainly cold or hot) are presented to soldiers.

Keynote 3

Wednesday 13th September, 08:45 to 09:30

Main Room



Professor Andrew Jones
PhD Dsci

Professor of Applied Physiology, University of Exeter

Andrew M Jones is Professor of Applied Physiology at the University of Exeter, UK. Prof Jones is internationally recognized for his expertise in the following areas: 1) control of, and limitations to, human skeletal muscle oxidative metabolism; 2) causes of exercise intolerance in health and disease; 3) respiratory physiology, particularly the kinetics of pulmonary gas exchange during exercise; and 4) sports performance physiology and nutrition. Prof Jones has published >350 peer-reviewed scientific articles with >38K citations, h-index of 107 and i10 of 305 (Google Scholar). Jones is Editor-in-Chief of the ACSM's flagship journal, Medicine & Science in Sports & Exercise and a member of the editorial boards of several other leading journals in the exercise sciences. Prof Jones has a keen interest in the translation of sports science research to aid elite sports performance and he has served as a consultant to UK Athletics, the English Institute of Sport and Nike Inc.

Thematic Sessions 12 to 15

Wednesday 13th September, 09:45 to 11:15

Thematic 12: Human augmentation to deliver an enhanced and resilient people capability for defence

Main Room

Description

Human Augmentation is 'the use of science or technology to temporarily or permanently modify human performance.' It encompasses a wide range of science and technology areas including wearable assistive technologies, neurotechnology, pharmacology, genetics, and regenerative medicine. This session will explore the benefits, opportunities, and challenges with using Human Augmentation Science and Technology to enhance the people component of military capability. The session will provide an overview of the range of Science and Technology that could be applied to augment human physical and cognitive performance as well as discussing the ethical and legal considerations of enhancing service personnel. A range of military applications for Human Augmentation Science and Technology will be highlighted with a particular emphasis on the future operating environment as well as demonstrating the current evidence base that underpins the potential for enhancing performance.

Background

From first tools, to flight, to advances in medicine and modern technology, enhancing our innate abilities has been a constant fascination. Indeed, militaries have long sought to advance the limits of human performance in their people. However, more recent and rapid advances in the fields of life sciences and biotechnology as well as the convergence of fields such as artificial intelligence, robotics, and medicine present a radically different opportunity for optimising and enhancing human performance. Indeed, NATO has identified biotechnology and human enhancement technologies as one of eight areas of emerging and disruptive fields in Science and Technology. Understanding the potential of these fields to offer strategic advantage in a defence environment, whilst simultaneously understanding the ethical and legal permissibility of such Science and Technology, is critical for defence organisations if they are to realise the role of Human Augmentation for providing an advantage to the future warfighter.

Military Impact

With the global investment in Science and Technology fields pertinent to Human Augmentation increasing, defence organisations around the world are increasingly interested and invested in understanding how those fields could be applied to enhance service personnel's performance; whether it be to increase their endurance and survivability or prevent out of duty time and / or accelerate return to duty after injury. However, the possibilities for the enhancement of service personnel raise important ethical and legal concerns, some of which will be unique to the military environment. Therefore, this highly topical thematic session, will give insights to defence researchers, policy makers, and senior decision makers in determining which human enhancement strategies within a military environment are most relevant and how / when they could be applied to enhance mission success.

Presentations

Chair: *Sarah Kemp, Defence Science and Technology Laboratory, UK*

Speakers and Titles:

09:45 – 09:50: Opportunities and challenges for human augmentation in defence and security

Sarah Kemp, Defence Science and Technology Laboratory, UK

09:50 – 10:05: Investigating the potential of non-invasive brain stimulation to augment cognitive functioning

Yvonne M Fonken, The Netherlands Organization for Applied Scientific Research (TNO), The Netherlands

10:05 – 10:20: Avatar: closer than you think. Moving telexistence concepts to reality

Nicola Armstrong, Defence Science and Technology, UK

10:20 – 10:35: Pharmacological performance enhancement and the military: exploring an ethical and legal framework for 'Super Soldiers'

Nathalie Pattyn, Royal Military Academy, Belgium

10:35 – 10:50: Ethical, legal, and societal aspects of human performance enhancement / augmentation

Koen Hogenelst, The Netherlands Organization for Applied Scientific Research (TNO), The Netherlands

10:50 – 11:15: Questions and discussion

Thematic 13: Spinal related injury in fast jet aircrew: identifying and supressing the threat to operational capability

Room 1

Description

This session will explore the issue of spinal related pain and its effect on operational capability in fast jet aircrew. Using the sequence of injury prevention as a framework, this session will provide an overview of: 1) establishing the problem, and how to best address the issues surrounding injury surveillance in military populations (particularly fast jet aircrew); 2) understanding aetiology and potential mechanisms that contribute to the experience of spinal related pain in military aircrew, and; 3) proposed interventions for addressing the problem (i.e., preventing the occurrence, and/or optimising rehabilitation following the occurrence) of spinal related pain in military aircrew. The session aims to provide an overview of: 1) recent advances in research that are assisting military organisation across multiple nations to better understand and address the problem, and; 2) opportunities to overcome gaps within the current literature of spinal related pain in military aircrew.

Background

Fast jet aircrew suffer from musculoskeletal pain, particularly that related to the spinal regions (back and neck). This pain can often result in degraded operational capability via: reduced performance during sorties, reduced availability for undertaking sorties, dropout during training, and early career termination. In addition to the impact on the health of individual aircrew, it can present a costly problem to military organisations given the time and money required to train aircrew. Undertaking meaningful research with military populations, particularly aircrew, can be difficult for a variety of reasons including: security, access, variable seeking of medical attention, hesitancy with providing personal medical related information, and difficulty with consistent follow-up. As a result, the literature on injury prevention among military aviators can often look underwhelming in comparison to other fields of injury prevention. However, recent efforts from multiple nations have seen some notable advances in this field.

Military Impact

With advances in the performance and manoeuvrability of military aircraft, and the increasing utilisation of body worn and helmet mounted equipment, the loads placed upon aircrew are increasing. With increased loads comes the potential for increased risks of injury, and thus impaired operational capability. By better measuring the extent of the problem, identifying the factors contributing to risk of injury, and understanding how to address the barriers in undertaking research with military aircrew, military organisations can better protect their valuable assets, and minimise avoidable impacts upon operational capability. Practical recommendations on injury surveillance, measurable risk factors, and prevention interventions including rehabilitation, will be discussed based upon the results of our recent scientific work. Where evidence is lacking, areas for novel future research will be identified

Presentations

Chair: *James Wallace, University of Canberra Research Institute for Sport and Exercise, Australia*

09:45 – 09:52: Session introduction: establishing the problem

James Wallace, University of Canberra Research Institute for Sport and Exercise, Australia

09:52 – 10:05: Identifying risk factors is imperative in reducing the costly burden on neck pain in fast jet aircrew: results of a two-year prospective study

James Wallace, University of Canberra Research Institute for Sport and Exercise, Australia

10:05 – 10:18: Neck flexor endurance test performance in Typhoon pilots: normative data and the relationship with flight-related neck pain

Joanna Magill, Royal Air Force, UK

10:18 – 10:31: Association between cervical range of motion and degenerative spine changes among fighter pilots

Tuomas Honkanen, Finnish Defence Forces, Finland

10:31 – 10:44: A wearable sensor system for in-flight measurement of neck loads in fast jet aircrew: key observations from typical air combat manoeuvres

Phil Newman, University of Canberra Research Institute for Sport and Exercise, Australia

10:44 – 10:57: Prehabilitation for fast jet aircrew and its effect on flight-related neck pain and performance

Ellen Slungaard, Royal Air Force, UK

10:57 – 11:15: Questions and discussion

Thematic 14: Modernising the human information data ecosystem to facilitate soldier performance optimisation

Room 2

Description

This session will detail the information technology infrastructure required to modernise the data-centric acquisition, development, employment, and retention of servicemembers. It will cover the integrative backend cloud architecture, connections between tactical and strategic data sources / storage, front end user interfaces, and software for data input and visualisations to drive information consumption to optimise performance, and explore the implication of these systems on human performance programs, practitioners, and performers. Past, present, and future science and technology applications across defence training and operations will be highlighted at all levels of action. This session aims to advance the comprehensive understanding of what, how, and why national defence efforts require improvements in human information dimension capabilities to keep up with pacing threats around the world.

Background

Soldiers are the foundation of every military capability. Incorporating modern technology and data analytics into the delivery of human performance training is crucial to maintaining the tactical edge and addressing threats to readiness. As industry pushes the information technology revolution to progress at lightning speed, defence organisations must embrace this change and leverage integrated systems on both macro and micro-levels. However, most conventional efforts and standardised practices are inhibited from employing commercial human performance data management systems. Given the persistent goal of maintaining healthy and fit servicemembers who are ready and willing to fight, win wars, and return home, this limitation must be immediately overcome. Research and development efforts have employed similar methods to devise new scientific knowledge, but these capabilities must be transitioned to training and operations. Establishing a modernised human performance data ecosystem inside enterprise-level solutions would provide the technology, tools, and actionable information to enhance readiness, resilience, and lethality.

Military Impact

This session impacts every level of defence organisations. It sets the stage for evolving information-driven human performance management to meet the following modernisation demands (DOTmLPF-P): developing doctrine to disseminate tactics, techniques, and procedures for actioning human dimension data; facilitating organisational culture change to generate leader and led adoption; advancing the science of personnel training and education to create and sustain operationally ready forces; implementing materiel solutions to measure, assess, and improve performance indicators; empowering leadership with human dimension data to inform decisions; allocating personnel to directly focus on holistically supporting warfighter development; modifying facilities to meet IT requirements, and; altering policies, regulations, and orders to promote and enable the entire approach. Each of these elements is critical to enhancing soldier health, fitness, and performance in multi-domain operations. The systemic implementation of concepts in this session will directly address current recruiting challenges faced by declining general population fitness, while also lessening the long-term health and financial burdens of veteran disease and disability. While its immediate effects directly impact national security, the cumulative influences of this work extend far beyond military employment, with vast implications on athletics, healthcare, global wellness, and quality of life.

Presentations

Chair: *Andrew G Thompson, US Army Center for Initial Military Training TRADOC, USA*

09:45 – 10:01: Developing and employing a data-driven architecture for enabling Soldier performance management

Andrew G Thompson, US Army Center for Initial Military Training TRADOC, USA

10:01 – 10:17: Creating and deploying information interfaces to support programmatic decisions, drive practitioner activities, and facilitate performer optimisation

Josh A Hagen, The Ohio State University Human Performance Collaborative, USA

10:17 – 10:33: Leveraging data ecosystems to inform human performance program operations, evaluation, and evolution

Alex E Morrow, US Space Force, USA

10:33 – 10:49: The human performance practitioner's playbook for embracing technological revolution to empower servicemember success

Rob P Hartman, Bridge Athletic, USA

10:49 – 11:05: The servicemember's perspective: why should I buy-in to the hype of human performance data

Jason B Clark, BeaverFit, USA

11:05 – 11:15: Questions and discussion

Thematic 15: Soldier performance management: insights from boots on ground research

Room 3

Description

The aim of this thematic session is to demonstrate how wearable devices and biomarkers have been used in defence research to assess the context specific demands placed on personnel, and their potential to monitor and optimise training. Theoretically, the serial administration of such measures could be used to better understand recovery status of personnel between military activities. This information could be used to assist with managing operational tempo, asset allocation, and force readiness, while enhancing long term health and career outcomes of personnel. Following the presentations, the speakers will facilitate a discussion between the panel and audience members resulting in a synthesises of the collective findings to provide advice for future ongoing approaches to monitoring and generating actionable outcomes from data capture.

Background

Operatives are at risk of injury and negative long-term health outcomes if workload is not appropriately managed across their career. Short term implications of improperly managed workloads include increased incidents of illness, increased injury risk, and decreased occupational performance and readiness. In other contexts, a range of subjective and objective measures have been used to monitor adaptation, optimise performance potential, and inform the programming of training. However, a challenge faced by our defence organisations is the cost and scalability of many of these initiatives. Recent research efforts have begun to explore the potential utility of implementing a range of measures in defence contexts. The findings of which will be presented here in this session.

Military Impact

In the context of military training and operations, simple and effective methods are required to monitor workload, training programming, and adaptation to multi-stressor environments. There are a range of non-invasive measures that present as relatively inexpensive and scalable options. These can be used to gather data which can be utilised to produce actionable outcomes to improve the readiness of personnel and manage workloads to mitigate the risk of illness and injury.

Presentations

Chair: *Luana Main, Deakin University, Australia*

Speakers and Titles:

09:45 – 10:00: Monitoring the personnel responses to military training

Luana Main, Deakin University, Australia

10:00 – 10:15: Monitoring the physical demands of specialist weapons training

Tessa Maroni, University of Chichester, UK

10:15 – 10:30: Objectively measured occupational physical load during military training and operations

Tommi Ojanen, Finnish Defence Forces, Finland

10:30 – 10:45: Physiological and cognitive determinants of soldier resilience during military operational stress and training

Bradley C Nindl, University of Pittsburgh, USA

10:45 – 11:15: Questions and discussion

Oral Communication 10: Female Health and Physiology

Wednesday 13th September, 11:45 to 13:15

Main Room

Chair: *Kristen J Koltun, University of Pittsburgh, USA*

11:45 – 12:00: Menstrual function, eating disorders, low energy availability, and physical performance in Army Servicewomen

Charlotte V Coombs [1], Caitlin Perrett [2], Rebecca L Knight [1], Sophie L Wardle [1], Julie P Greeves [1], Thomas J O'Leary [1]

[1]Army Health and Performance Research, UK
[2]UCL, UK

Purpose: Women in the British Army are at risk of low energy availability and menstrual disturbances, but the relationship between these outcomes and physical performance is unknown. This study aimed to investigate associations between physical performance and menstrual function, eating disorders, and risk of low energy availability in Army Servicewomen. **Methods:** All women under 45 years in the British Army were invited to complete a custom-designed online questionnaire divided into: demographics, job role, risk of disordered eating, exercise behaviours, menstrual function, and physical performance. Inferential statistics were performed with ordinal logistic regression to assess the association of 2 km run time and maximal effort deadlift strength with the predictor variables: menstrual function, risk of eating disorders, and risk of low energy availability, when controlling for demographic factors and time spent physical training. **Results:** 1,341 women participated; 825 were included for analyses following the exclusion of individuals who were either pregnant or had not completed any military physical fitness tests in the last 12 months. Having a menstrual disturbance (oligomenorrhoea / amenorrhoea) was not associated with 2 km run time (odds ratio (OR) [95% confidence intervals], 1.24 [0.59, 2.60] $p = 0.56$) or deadlift strength (1.09 [0.53, 2.23], $p = 0.82$) compared with eumenorrheic women. High risk of an eating disorder (Female Athlete Screening Tool score > 94) was not associated with 2 km run time (1.17 [0.61, 1.25], $p = 0.63$) or deadlift strength (0.87, [0.44, 1.68], $p = 0.67$) compared with low risk of an eating disorder. High risk of low energy availability (Low Energy Availability in Females Questionnaire score ≥ 8) was not associated with 2 km run time (1.28 [0.84, 1.95], $p = 0.26$) or deadlift strength (1.00 [0.68, 1.61], $p = 0.84$). **Conclusions:** Military-specific physical performance was not influenced by indicators of menstrual function, eating disorders, or risk of low energy availability in Army servicewomen; other factors in a multi-stressor environment might be involved in influencing performance. **Military Impact:** Strategies that focus on improving menstrual function, eating disorders, and low energy availability may be less effective for improving physical performance in Servicewomen compared with other approaches.

12:00 – 12:15: Severity of menstrual cycle symptoms among UK servicewomen when performing work-based tasks

Phoebe Thomas [1], Rebecca L Knight [1], Thomas J O'Leary [1], Sophie L Wardle [1], Julie P Greeves [1]

[1]Army Health and Performance Research, UK

Purpose: Cyclic hormonal fluctuations throughout the menstrual cycle can result in physical

and psychological symptoms such as stomach cramps (dysmenorrhoea), bloating, and anxiety. These symptoms typically occur in the luteal phase of the menstrual cycle and can negatively impact occupational performance, concentration, and rates of absenteeism. Servicewomen are often required to conduct physically and cognitively demanding tasks, but the extent to which these tasks are impacted by menstrual cycle symptoms remains poorly understood. This cross-sectional study investigated the severity of fifteen specific menstrual-related symptoms among non-hormonal contraceptive users when performing both physical and cognitive tasks. **Methods:** An online survey was distributed to all women (n = 14,500) serving in the UK Armed Forces (regular and reserve) (aged ≥ 18 y). A 5-point Likert scale was used to score each symptom during physical and cognitive tasks, ranging from "1, I never experience this symptom" to "5, the symptom always impacts tasks at work". Data were analysed using one-way ANOVAs and post-hoc tests were used to evaluate differences between age groups and services. Paired t-tests were used to compare the impact of each symptom (mean Likert score) between physical and cognitive tasks. **Results:** 4,438 women responded (31%), of which 37% (n = 1,658) were non-hormonal contraceptive users. 66% of participants reported dysmenorrhoea negatively impacted physical and cognitive tasks. Paired t-tests revealed dysmenorrhoea, backache, and bloating impacted physical tasks more than cognitive tasks ($p < 0.001$) whereas headaches ($p = 0.043$) and trouble sleeping ($p < 0.001$) caused more disruption to cognitive tasks. Women in a younger age category (18 to 24 y) perceived dysmenorrhoea to impact physical tasks more (3.6) than those aged 30 to 34 y (3.1, $p = 0.045$), 35 to 39 y (3.1, $p = 0.010$), and ≥ 40 y (2.9, $p < 0.001$). The reported negative effects of trouble sleeping on physical tasks were not associated with age, though those aged 18 to 24 y found trouble sleeping impacted cognitive tasks more than those aged 30 to 34 y (3.0 vs 2.38, $p = 0.006$), 35 to 39 y (2.3, $p = 0.001$), and ≥ 40 y (2.3, $p = 0.001$). Army servicewomen perceived breast pain to negatively impact physical tasks more than Royal Air Force servicewomen (2.2 vs 2.0, $p = 0.008$). **Conclusions:** Dysmenorrhoea was reported as having the most impact on work-related tasks. Symptoms exhibited varying effects upon physical and cognitive tasks, and younger personnel were more likely to undertake physical tasks which may explain increased disruption during their roles. **Military Impact:** Awareness of the dominant menstrual cycle symptoms affecting work-related tasks, and knowledge of the population most affected, is important to target education on symptom-management and medical treatment to support servicewomen throughout their military career.

12:15 – 12:30: Characteristics associated with pelvic floor disorders among female Canadian Armed Forces members

Jessica L Puranda [1], Danilo F da Silva [2], Francine Darroch [3], Chris M Edwards [1], Taniya S Nagpal [4], Sara S Souza [1], Kevin Semeniuk [1], Linda Mclean [1], Kristi B Adamo [1]

[1]University of Ottawa, Canada
[2]Bishop's University, Canada
[3]Carleton University, Canada
[4]University of Alberta, Canada

Purpose: Urinary incontinence (UI) and pelvic organ prolapse (POP) are prevalent pelvic floor disorders (PFDs) among the female population. Being a non-commissioned member (NCM), and physically demanding occupations are military factors associated with PFD. This study seeks to investigate experiences associated with PFDs and characterise the profile of female Canadian Armed Forces (CAF) members reporting symptoms of UI and / or POP. **Methods:** Present and former CAF members responded to an online survey and / or participated in focus group sessions with the purpose of obtaining pan-Canadian and CAF-specific feedback on experiences, risk profiles, socio-cultural, and perceived support or barriers related to reproductive health (i.e., pregnancy and postpartum) and musculoskeletal injury (MSKi). Self-reported symptoms of UI and POP were collected. Multivariate logistic regressions were used to analyse the relationships between PFD symptoms and associated characteristics (i.e., age, BMI, rank structure, parity, occupational physical demands). Focus group data were assessed with Nvivo 1.3.2 to generate themes related to physical training, MSKi, pregnancy, and perceived barriers to career progression. **Results:** 765 active female members participated in an online survey. The prevalence of self-reported POP and UI symptoms were 14.5% and 57.0%, respectively, with 10.6% of respondents reporting both PFDs. Advanced age (adjusted odds ratio (aOR) [confidence interval]: 1.062 [1.038 – 1.087]), an obese BMI classification (aOR: 1.909 [1.183 – 3.081]), parity ≥ 1 (aOR for 1: 2.420 [1.352 – 4.334]) and being a NCM (aOR: 1.662 [1.144 – 2.414]) were associated with urine leakage. Parity of ≥ 2 (aOR: 2.351 [1.370 – 4.037]) compared to nulliparous and reporting to have a physically demanding job (aOR: 1.933 [1.186 – 3.148]) were associated with experiencing POP symptoms. Parity of ≥ 2 increased the odds of reporting both PFD symptoms (aOR: 5.709 [2.650 – 12.297]). Thirtytwo female respondents who experienced pregnancy while serving in the CAF participated in focus groups. Focus group participants reported a lack of knowledge, resources and / or support surrounding pelvic floor health, particularly in the postpartum period. Symptoms of UI and POP were reported to occur during, and interfere with, training. **Conclusions:** PFD symptoms are prevalent among female CAF members. Parity was associated with a greater chance of experiencing symptoms of UI and POP. Older age, higher BMI, and being an NCM were associated with more symptoms of UI, and the perception of having a physically demanding role increased the likelihood of reporting POP symptoms. Parous members report experiencing PFD symptoms that interfere with their duties and would benefit from additional support. **Military Impact:** PFD should be considered a prevalent issue among female CAF members and further policies/programs aimed at addressing PFDs are needed.

12:30 – 12:45: Evaluating the sports bra fitting and issue service within British Army basic training

Jenny Burbage [1], Emily Paines [1], Gemma Milligan [1], Mike Tipton [1], Alex J Rawcliffe [2], Andrew J Roberts [2]

[1]University of Portsmouth, UK
[2]HQ Army Recruiting and Initial Training Command, UK

Purpose: A sports bra fitting and issue service for British Army female recruits undertaking basic training (BT) was introduced in 2019. It is currently unknown whether the sports bras

provided are suitable for the needs of female recruits during BT. This study aimed to evaluate the current sports bra fitting and issue service and investigate the prevalence of breast and bra issues of female recruits during BT. **Methods:** Following ethical approval (2036MODREC21), 229 recruits and officer cadets completed questionnaires at the end of BT to collect information on sports bra use and preferences. Questionnaire data were descriptively analysed and Chi-squared goodness-of-fit tests were used to determine associations between breast size groups (small-breasted [500 g, n = 170] and large-breasted (> 500 g, n = 51]), and between BT sites. Seven recruit interviews were subsequently recorded, and an inductive content analysis conducted. **Results:** Sixty percent of recruits (57% of small-breasted; 72% of large-breasted) wore the sports bras provided by the sports bra fitting and issue service. Seventy-six percent of recruits wore a sports bra for > 8 h·d-1 and 59% did not change their bra during the day. A total of 134 breast or bra issues were reported; 61% of recruits reported one or more problems with the issued sports bras, which was 18% less than that reported prior to the introduction of sports bra provision. The most common issues reported included: comfort (24%); quantity (21%); size (17%); fit (17%); and style (11%). Key problems highlighted were fluctuations in breast size affecting fit and not enough sports bras or fittings to meet the demands of BT. **Conclusions:** The current sports bra fitting and issue service has reduced breast and bra-related issues by 18%. No significant associations were found between breast size or BT site and the amount of breast and bra issues experienced. However, problems relating to the issued sports bras and current service provision suggests further improvements to provision could be made and research is required to determine the most suitable sports bra provision relative to the demands of BT. **Military Impact:** Evaluating the sports bra fitting and issue service within BT has provided recommendations for future service provision and informed research investigating sports bra characteristics that are most suitable for short and long duration wear. From this work recommendations can be made concerning the most suitable types of sports bras to issue to female recruits in the British Army.

12:45 – 13:00: A job task analysis to identify basic training activities that place the highest demands on the breasts of female recruits

Gemma Milligan [1], Emily Paines [1], Jenny Burbage [1], Mike Tipton [1], Alex J Rawcliffe [2], Andrew J Roberts [2]

[1]University of Portsmouth, UK
[2]HQ Army Recruiting and Initial Training Command, UK

Purpose: Sports bras are necessary items of equipment for female recruits in basic training (BT). Sports bras are designed for short duration, high-intensity activities, such as running. To provide suitable sports bras for recruits we first need to understand the functional requirements relative to the demands of BT. This study aimed to determine the components of BT regarded as the most demanding on the breast and therefore in most need of suitable breast support. **Methods:** Ethical approval was obtained (2036/MODREC/21). A task analysis of BT was undertaken using a multi-levelled approach, including: semi-structured interviews with subject matter experts (SMEs, n = 8 members of training teams); a review of BT manuals, and; questionnaires (n =

221) and interviews (n = 7) completed by recruits and officer cadets. Audio interview recordings were transcribed and subsequently reviewed by the same research team member. Responses to the questionnaire were collected and coded in Lime Survey. **Results:** The most frequently identified physically demanding tasks, by both SME and recruits, were: loaded marching, fire and movement, and physical training (PT) sessions, which included strength and conditioning and outdoor PT (i.e., battle PT, combat PT, and obstacle courses). There was an overlap between the activities perceived as the most physically demanding and those that most needed breast support. Loaded marching, gym cardio, outdoor PT, and fire and movement were perceived as both physically demanding and requiring the most breast support. Tasks that were considered to have lower physical demands, such as foot drill and range activities, were still perceived to need a sports bra. **Conclusions:** Based on these results we cannot assume that only the most physically demanding tasks of BT require sports bras, therefore it is important to determine suitable sports bras to reduce breast related issues and that meet both physical and breast demands of BT. Findings from this study have supported further research on sports bras for military specific tasks, which has enabled recommendations of key sports bra characteristics to be made relative to the physical and breast demands of BT. **Military Impact:** With the number of female recruits training to be in the British Army increasing, the investigation of issues relating to female-specific health and well-being is required. This research identified military tasks which are most demanding on the breast during BT, informing future research into sports bras for female recruits. Findings have the potential to inform the procurement of suitable sports bras for females in BT and the wider field army.

13:00 – 13:15: A comparison of issued sports bras and determination of sports bra characteristics required to undertake British Army basic training

Emily Paines [1], Jenny Burbage [1], Gemma Milligan [1], Mike Tipton [1], Alex J Rawcliffe [2], Andrew J Roberts [2]

[1]University of Portsmouth, UK
[2]HQ Army Recruiting and Initial Training Command, UK

Purpose: Despite the introduction of a professional sports bra fitting and issue service for British Army female recruits entering basic training (BT), a large proportion (61%) still report breast and bra issues. There is therefore a need to determine suitable sports bras for use in BT. This study investigated a variety of sports bra characteristics (e.g., strap configuration, style, padding) during short duration simulated BT tasks. **Methods:** Ethical approval was obtained (2128/MODREC/22). Military tasks (burpee, foot drill, drop landings, running, and loaded marching) were simulated in a laboratory identified from a prior task analysis. Twenty-five, age-matched female civilians, completed all tasks in four styles of sports bra (compression, combination [padded and unpadded], and encapsulation). Biomechanical and perceptual data were collected for each task and compared between sports bras. The four sports bras were ranked by participants for overall performance (e.g., support, comfort, rubbing) and key characteristics identified. One-way ANOVAs with post-hoc analysis was used to test differences in breast movement between sports bra conditions during running. **Results:** Combination and

encapsulation style bras reduced breast movement significantly more than compression style bras during running (by 15% to 18%, $p < 0.001$). The compression style sports bra was rated worst performing overall for running tasks by 64% of participants. Shoulder straps with high positioned top clasps were associated with greater rubbing and chafing which was exacerbated by load carriage equipment. The compression sports bra received the least comments about rubbing and chafing across tasks and was rated 2nd for comfort overall despite providing poor support. The combination (unpadded) style was rated highest as "very supportive" during foot drill, drop landing, and burpees. Across all tasks, participants ranked the combination (padded) sports bra as best performing and the compression sports bra as worst performing. However, 44% of participants also perceived the combination (padded) sports bra as "least likely" to be comfortable when worn over longer periods of time. **Conclusions:** A combination padded, or unpadded-style sports bra is recommended for running and military-like activities (e.g., foot drill, drop landing, and burpees), with encapsulation or compression style for loaded marching. Further research is underway to determine whether the same sports bra characteristics identified for short duration use can be recommended for long duration wear in BT. **Military Impact:** This research provides recommendations not only for the current provision of sports bras within BT but also for trained soldiers in the wider army undertaking similar tasks.

Oral Communication 11: Data Analytics and Predictive Modelling

Wednesday 13th September, 11:45 to 13:15

Room 1

Chair: *Andrew Siddall, Defence Science and Technology Laboratory, UK*

11:45 – 12:00: Prospective validation of 2B-Cool: integrating wearables and individualized predictive analytics to reduce heat injuries

Jaques Reifman [1], Srinivas Laxminarayan [1], Samantha Hornby [1], Luke N Belval [2], Gabrielle E W Giersch [2], Margaret C Morrissey [2], Douglas J Casa [2]

[1]United States Army Medical Research and Development Command, USA
[2]University of Connecticut, USA

Purpose: An uncontrollably rising core body temperature (T_C) is an indicator of an impending exertional heat illness. However, measuring T_C invasively in field settings is challenging. In contrast, wearable sensors combined with machine-learning algorithms can continuously estimate T_C non-intrusively. Here, we prospectively validated 2B-Cool, a hardware / software system that automatically learns how individuals respond to heat stress and provides individualised estimates of T_C, 20 min ahead predictions, and early warning of a rising T_C. **Methods:** We performed a crossover heat-stress study in an environmental chamber, involving 11 men and 11 women (mean age = 20 ± 2 y) who performed three bouts of varying physical activities on a treadmill over a 7.5 h trial, each under four different clothing and environmental conditions. Participants wore the 2B-Cool system, consisting of a smartwatch, which collected vital signs, and a paired smartphone, which housed machine-learning algorithms and used the vital sign data to make individualised real time forecasts. Participants also wore a chest strap heart rate sensor and a rectal probe, for comparison purposes. **Results:** We observed very good agreement between the 2B-Cool forecasts and measured T_C, with a mean bias of 0.16°C for TC estimates and nearly 75% of measurements falling within the 95% prediction intervals of ± 0.62°C for the 20-min predictions. The early warning system results for a 38.50°C threshold yielded a 98% sensitivity, 81% specificity, prediction horizon of 35 min, and a false alarm rate of 0.12 events per hour. We observed no sex differences in the measured or predicted peak T_C. Conclusions: 2B-Cool provides early warning of a rising T_C with a sufficient lead time to enable clinical interventions and help reduce the risk of exertional heat illness. **Military Impact:** 2B-Cool may be a useful tool to monitor rises in T_C caused by physical activities in hot and humid environments irrespective of sex for a prolonged period, allowing Service members to make informed decisions in a field setting to reduce the risk of exertional heat illness.

12:00 – 12:15: The utilization of wearables to develop methods and metrics for assessing collective small unit lethality and in-field performance

Meghan O'Donovan [1], Clifford Hancock [1], Eric Sikorski [2], Michael King [2], Grace Teo [2], Gregory Goodwin [1]

[1]DEVCOM SC, USA
[2]Quantum Improvements Consulting, USA

Purpose: The proliferation of wearable technologies has led to an increase in the data and information that can be collected during military operations. Such technologies primarily track data at the individual level. However, infantry operations require higher-level echelons (e.g.,

squad, platoon) to execute. Methods and metrics must be developed which directly measure collective behaviour to best quantify military in-field performance. **Methods:** 15 dismounted infantry squads were tested while conducting force-on-force engagements including Battle Drill 2A (BD2A) and 6 (BD6). Squads repeated the drills on three consecutive days. Squads were equipped with wearables focused on the following domains: Operational Effectiveness, Movement and Positioning, Lethality and Engagement, Communication, and Physiological Status Monitoring. Squads were rated by four military Observer Controllers (Ocs). Collective performance metrics were developed to (a) distinguish squads of varying proficiencies and (b) detect changes in performance due to repetition. The results presented here focus on BD2A. Data were subjected to regressions to predict measures of Operational Effectiveness or to ANOVAs to determine statistically significant ($\alpha \leq 0.05$) differences between squads or iterations. **Results:** Operational effectiveness scores generated by the Ocs for both battle drills increased ~ 21% across iterations, indicating an increase in squad proficiency with practice. The average squad movement speed also significantly increased ($p = 0.048$) across iterations. For BD2A, there were significant differences across squads including the spread of the formations ($p < 0.001$), the ratio of time spent shooting during the drill collected from weapon-mounted inertial measurement units (IMUs, $p = 0.028$), and squad security during contact collected from helmet-mounted IMUs ($p = 0.022$). These findings reflect differing techniques squads used to execute the drill. For BD2A, the proportion of leadership commands issued, total word count, total information exchange, and proportion of team leader questions answered all significantly predicted the operational effectiveness scores in a regression analysis ($R2 = 0.40$, $p < 0.001$). For BD2A, heart rate was significantly different between squads ($p < 0.001$), ranging between 69% and 91% of their maximum age-normalised heart rates, likely reflecting differences in overall fitness levels or stress response. **Conclusions:** These results show that wearable sensors can produce objective, collective performance measures, which distinguish between squads of varying proficiencies or across testing iterations as performance changes. These results provide a benchmark for how in-field performance quantification can be accomplished in operational scenarios and provide examples of key collective measures. **Military Impact:** Assessment methods, metrics, and predictive models must account for overall small unit effectiveness beyond the individual echelon to increase operational validity.

12:15 – 12:30: Monitoring training load in military settings using wearable devices: can we predict musculoskeletal injuries?

Einat Kodesh [1], Shany Funk [1], Maya Reiner [1], Veronika Bogina [2], Itay Ketko [3], Alexandra Rabotin [3], Tsvi Kuflik [1]

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[2]Tel-Aviv University, Israel
[3]IDF Medical Corps, Israel

Purpose: The use of wearable devices allows for the monitoring and assessment of training loads. Using wearable technology in the military setting, we aimed to: 1) prospectively monitor daily distance covered and heart rate (HR) to assess differences between those soldiers who sustained an injury during the training program and those who did not, and; 2) develop predictive models to identify the risk of injury before it occurs. **Methods:** A group of thirty-seven male special forces soldiers, aged 19-21, participated in the study. Data collection was carried out using Garmin smartwatches, continuously monitoring their activities during the final and most challenging five months of the 18-month training. Data collection included external load (daily distance), and internal load (daily average resting HR, daily HR zones [% of the daily time spent in HR zones 1 to 5]), as well as sleep variables. Injury data was collected by reviewing the participants' medical records. Injured and non-injured groups' outcomes were compared using a t-test. To identify the risk of injury prior to occurrence, a machine learning approach was employed. Data of injured participants were examined over time to detect the week during which variations in measurement patterns occurred before injury. Subsequently, all features' outcomes at the determined period of variation were compared to those soldiers who did not sustain an injury. **Results:** The actual weekly distance covered was higher than planned in most training weeks. Twenty-five soldiers (67%) sustained musculoskeletal injuries during the training program and were classified as "injured". The "injured" group demonstrated a lower average daily HR, spent a longer time at rest, and less time in the light-moderate active zone (HR zones 2-3) compared with the non-injured group ($p < 0.01$). Three weeks prior to the injury, soldiers covered greater distances ($p < 0.001$) and spent more time in the high HR zones (>140 bpm) relative to others ($p = 0.03$). Among injured soldiers, sleep duration increased ($p < 0.001$), while the duration of deep sleep decreased ($p = 0.03$) over the training period. **Conclusions:** The utilisation of wearable technology in military settings enables the development of predictive models that integrate the condition of each soldier relative to their squad. These monitoring devices can provide internal and external training patterns over time, thereby enabling the timely identification of potential injury risks. **Military Impact:** Incorporating wearable technology for measuring internal load in the military setting could potentially facilitate monitoring of how soldiers cope with, and adapt to, training loads, and, ultimately, assist in tailoring the training program to mitigate musculoskeletal injuries.

12:30 – 12:45: Physical fatigue state classification through fusion of physiological and biomechanical metrics

Michael Vignos [1], John Clark [1], Connor Pyles [1], Marshall Tumperi [1], Kyle Ott [1], David Drewry [1], Ryan Roemmich [2], Jan Stenum [2], Nikki Steiner [1]

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Purpose: Physical fatigue monitoring could enable early detection of changes in performance and musculoskeletal injury risk. Previous research has demonstrated good accuracy in classifying physical fatigue state from wearable sensors. However, these approaches have not demonstrated success in generalising across activities. This limitation is potentially due to previous classification models using a single sensor type as input, given that fatigue manifests differently across different activities. Thus, the objective of this study was to develop and assess the accuracy of a model to classify physical fatigue state from a fusion of physiological and

biomechanical measurements. **Methods:** Joint kinematics, lower extremity electromyography, and ground reaction forces were collected in ten healthy volunteers (7 men, 3 women, 26.7 ± 5.8 y, 71.9 ± 12.3 kg, 1.77 ± 0.07 m) while they ran on a treadmill in baseline and fatigued states. In between the baseline and fatigued trials, participants were fatigued through a two-stage exercise protocol. The first stage consisted of participants running on a treadmill at a self-selected speed until they reached a Borg rating of perceived exertion of 17. The second stage consisted of a repeating circuit of 30 s of squats, 30 s of lunges, and 3 maximum vertical jumps until participants had 3 consecutive jumps below 80% of baseline. Features previously reported to change due to fatigue were computed from the baseline and fatigued trials. Subsequent feature selection consisted of statistical analysis to include features that differed between baseline and fatigued states, removal of highly correlated features, and recursive feature elimination based on model accuracy. This reduced the feature set from 912 to 15 features. Seven different fatigue classification models were trained with these 15 features. The accuracies of these models were evaluated through leave-one-subject-out cross-validation. **Results:** The final feature set consisted of nine electromyography, five kinematics, and one ground reaction force features derived from fourteen sensors. The cross-validation accuracy of the seven classification models ranged from 75.7% to 83.9% with linear discriminant analysis and logistic regression models being the most accurate. **Conclusions:** These results demonstrate that a fatigue classification model trained using electromyography, kinematics, and ground reaction force features achieves an accuracy better than or similar to previous fatigue classification models (75% to 91%) with electromyography being particularly beneficial for fatigue classification. Future work will investigate the generalisability of this model across activities, minimize the sensor suite, and correlate performance degradation and injury risk to level of physical fatigue. **Military Impact:** This study provides guidance on biomechanical and physiological metrics that can enable physical fatigue monitoring. Further model development could enable real-time predictions of warfighters' performance and musculoskeletal injury risk and be used to prevent injuries and optimize missions.

12:45 – 13:00: Consideration of individual factors when predicting target engagement decision making performance of expert shooters

Maria Talarico [1], David Scribner [1], Frank Morelli [1]

[1]US Army DEVCOM Analysis Center, USA

Purpose: There is no cogent, unified understanding of the human contribution to marksmanship performance. While most of the unexplained variance from shooting performance models stem from individual shooter factors, an overarching framework is required to explain performance differences with shooter characteristics as potential contributors. The goal of this effort was to identify individual factors that influence marksmanship performance. **Methods:** Six expert shooters completed a series of surveys and assessments prior to live-fire target engagement. Surveys queried demographics and shooting experience, fatigue, sleep quality, and self-efficacy. Baseline assessments recorded anthropometrics, visual acuity, heart rate, working memory, strength, and endurance / stability. Baseline shooting assessments included known distance qualification and a dynamic shooting task. Target engagement tasks featured three conditions: (1) workload (low / high), (2) target exposure (2 or 4 s), and (3) distance (25 / 50 / 100m). Low / high workload conditions included friendly and enemy discriminators, with exposure time and distance nested within a 24-target trial. Shooters performed three trials for both workloads and identified test components that imposed stress during firing. Hit percentage and radial error were calculated to quantify marksmanship. Multiple linear regressions using backward selection were fit with hit percentage and radial error as outcomes with fixed effects of experimental variables (friend / enemy, exposure time, and distance). Multiple regressions were also fit with the same outcomes with experimental variables and individual factors (full model). ANOVAs compared experimental variable models to full models to determine whether individual factors improved overall model performance. Alpha was set a priori at 0.05. **Results:** Experimental variable models explained 25.0% and 21.7% of variance while full models explained 28.1% and 30.0% of variance for hit percentage and radial error, respectively ($p < 0.01$). Individual factors included in both hit percentage and radial error full models were self-reported fatigue, weight training exercise (h·week-1), degree of sleepiness, right hand length, and working memory performance. **Conclusions:** Including individual factors for target engagement decision making in predictive models improved model performance and explained more variance than experimental variables alone. Accounting for individual factors is critical for more effective predictive modelling of shooting performance. **Military Impact:** To optimise human-system integration methodology, it is crucial to consider and include individual factors in marksmanship performance models. Small arms weapon development can benefit from multivariate performance methodologies to better inform acquisition / design decisions. As future weapon systems continue to be developed and fielded for the Warfighter, providing improved expected outcomes is an asymmetric advantage over methodologies that are more simplified and do not consider the human operating the system.

13:00 – 13:15: Novel target engagement metric for holistic quantification of marksmanship performance

Maria Talarico [1], David Scribner [1], Frank Morelli [1]

[1]US Army DEVCOM Analysis Center, USA

Purpose: A common practice within the small arms community is to use “gold-standard” marksmanship performance metrics, such as mean radial error (MRE) or hit percentage. These metrics, may not be sensitive enough to discriminate between shooters’ target engagement performance and discrimination ability. Shortcomings in quantifying marksmanship abilities produce misleading performance ratings for shooters. This may be especially relevant for decision-making during shoot / don’t shoot scenarios within marksmanship performance tasks, which increase mental workload for the Warfighter. The goal of this effort was to (1) develop a novel target engagement performance metric and (2) test the novel metric’s ability to quantify target engagement performance compared to legacy metrics. **Methods:** Six expert shooters completed target engagement tasks under three conditions: (1) friend / enemy target discrimination workload or level of difficulty (low / high), (2) target exposure time (2 or 4 s), and (3) target distance (25 m / 50 m / 100 m). Target exposure times and distances were nested within a 24-target trial for each workload. Shooters performed three trials for each workload-time-distance condition. Hit percentage and MRE were calculated for each enemy trial where a shot was taken. Target Engagement Discrimination (TED) Score is a point-based metric where points are given based on (1) target engagement decision (incorrect / correct) and (2) target engagement outcome (hit / delay / miss). Points were summed for a trial TED Score and then averaged across the three trials for an overall TED Score. A larger TED Score indicated better target engagement discrimination performance. Linear multiple regressions were fit with hit percentage, MRE, and TED Score as outcomes with fixed effects of experimental variables (friend / enemy, exposure time, and distance). Regressions were run to determine if TED Score (novel metric) outperformed hit percentage and MRE (legacy metrics) in quantifying individual shooter performance based on friend / enemy decision making, target exposure time, and target distance. Alpha was set a priori at 0.05. **Results:** The TED Score model did not perform better (R2 = 0.07, $p < 0.001$) than that of hit percentage (R2 = 0.28, $p < 0.001$) and MRE (R2 = 0.09, $p < 0.001$). **Conclusions:** A novel metric that accounts for decision making outcomes and shooting experimental variables did not perform better than legacy metrics in effectively quantifying target engagement discrimination ability. The weaker association between TED Score and experimental variables suggests a model that warrants further investigation and consideration when predicting marksmanship performance. Appropriate human performance predictive tools are critical to occupations where marksmanship qualification and performance is vital. **Military Impact:** Further statistical development of this novel marksmanship metric aims to create a standardised method of quantifying target engagement discrimination performance, regardless of study design and varying experimental variables. TED Score may also provide a more comprehensive, effective way to evaluate individual shooter performance for occupational / MOS qualification and duty obligations that bolsters traditional military metrics for assessing target engagement performance.

Oral Communication 12: Cognitive Performance

Wednesday 13th September, 11:45 to 13:15

Room 2

Chair: *Nicola Armstrong, Defence Science and Technology Laboratory, UK*

11:45 – 12:00: The impact of winter warfare training on physiological stability and stress reactivity

Karen R Kelly [1], Andrea Givens [1], Jake R Bernards [1], Laura Palombo [1]

[1]Naval Health Research Center, USA

Purpose: Cold exposure and movements in harsh winter terrain is a core component of military operators assigned to mountain and mobility teams. Pathophysiological changes occur to increase metabolism and maintain body heat. Environment impacts daily variation in hormone responses, but there is little data on the compounding effects of cold exposure and military winter training. Thus, the purpose of this effort was to measure daily stress response in elite military during winter warfare training. **Methods:** Thirteen elite mountain and mobility operators (male: n = 12, female: n = 1; age: 31.5 ± 1.4 y; height: 1.81 ± 0.01 m; body mass: 87.3 ± 3.0 kg; body fat: 18 ± 1.3%; VO_{2peak}: 46.7 ± 1.2 $mL \cdot kg^{-1} \cdot min^{-1}$) were recruited for this study. Participants engaged in baseline laboratory metrics one month prior to engaging in 6 consecutive days of winter warfare training. Salivary biomarkers (dehydroepiandrosterone (DHEA), total testosterone, cortisol, alpha-amylase (AA), and osteocalcin were collected prior to and immediately post-training each day. Core and skin temperature were recorded each day. Pre- and post-each day a rapid cognitive test was administered. **Results:** Morning cortisol increased ($p = 0.01$) from baseline to first day of training. Mixed effects model showed that there was a significant difference across each training day for morning value of AA ($p < 0.05$), whereas all other biomarkers remained stable. Further, there was a significant interaction effects (the changes of pre vs post concentrations) across six days of training ($p < 0.0001$) for all biomarkers. Simple contrasts revealed training days 2-4 provoked the greatest change in all biomarkers with significant AA increase ($p < 0.05$) and decreases in all other biomarkers ($p < 0.05$). There was no relationship between metabolic biomarkers (cortisol and osteocalcin) and blood glucose. There was a moderate correlation between cortisol and testosterone ($r = 0.57$), cortisol and DHEA ($r = 0.67$), and testosterone and DHEA ($r = 0.63$). There was a weak correlation between simple reaction time and AA ($r = –0.33$). There were no changes in core or mean skin temperature throughout the training day. **Conclusions:** The stress response pathways are essential for maintenance of physiological stability in response to both environmental and physical stress. Data form this study highlights the complex reciprocal counterbalances between the two stress pathways sympathetic adrenal medullary SAMs (AA) and hypothalamic pituitary adrenal (HPA) axis (cortisol). Stress-induced chronic stimulation and dysregulation of these systems may lead to long-term metabolic abnormalities and hyporesponsive HPA axis and has been linked to increased susceptibility to chronic illness. **Military Impact:** Monitoring stress response and reactivity is an objective measure of stress resilience as well as an indicator of overall health for operators in physically demanding occupations.

12:00 – 12:15: Training to perform or learning to train? Factors associated with performance in close quarter urban operations training may have limited transfer to real world performance

Daniel Cooper [1], Tim Doyle [1], Mark Wiggins [1], Jodie Wills [1], Luana Main [2]

[1]Macquarie University, Australia
[2]Deakin University, Australia

Purpose: Decision-making in use-of-force relies on the accurate identification of visual information, or cues to inform the appropriate response. However, developing this capacity depends on several factors including those visual features contained within the training environment to associate the most appropriate response for perception and action coupling. The aim of this research was to examine the relationship between cue utilisation and performance in separate urban operations training environments. Comparisons were made between the development of cue utilisation within a reality-based training environment and a traditional training environment, and performance on a positive identification and a shoot – don't shoot task. **Methods:** A total of 51 participants were assessed, separated across three groups: trainees undergoing an urban operations training course utilising reality-based training (n = 24), a control group undertaking traditional range based urban operations training (n = 20), and an experienced instructor group (n = 7). Participants completed cue utilisation measures prior to, and following training, with between groups changes, successful or unsuccessful training course outcome (Trainee Group) and performance on a positive identification, shoot – don't shoot task recorded. **Results:** A significant main effect was evident for cue utilisation and timepoint of assessment, ($p = 0.005$), but not between groups and timepoint, ($p = 0.410$). No main effect was evident between groups and training outcome, ($p = 0.11$). However, there was a main effect for timepoint of assessment, ($p = 0.02$) and an interaction for training course outcome and timepoint of assessment ($p = 0.02$). The results revealed a statistically significant difference in cue identification and recognition between real-world and training-based cues following participation in training. There was no statistically significant relationship between cue utilisation and performance on positive identification task nor improvements in operational performance as a result of training. **Conclusions:** Although cue utilisation is an essential component of perception-action tasks, the development of recognition and identification may be more specific to the cues contained within a training environment with limited transfer to real-world performance or positive effect on a shoot don't-shoot task. **Military Impact:** Although cue utilisation is an essential component of perception-action tasks, cue development may be specific to the training environment with limited transfer to real world performance. This should be carefully considered when designing training environments to ensure they contain adequate contextually relevant features to provide appropriate transfer of training to operational environments.

12:15 – 12:30: Implementation and validation of the Acute Readiness Monitoring Scale (ARMS) in the Australian Army

Joshua M Adie [1], Richard J Keegan [1], Simon J Summers [2], David Crone [3]

[1]University of Canberra, Australia
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[3]Defence Science Technology Group, Australia

Purpose: Between August to December 2019, a new psychometric scale for measuring acute, multidimensional readiness in the Australian Army was developed. The Acute Readiness Monitoring Scale (ARMS) enabled quick, low-impost check-ins for up to nine readiness indicators: (1) overall readiness; (2) physical readiness; (3) physical fatigue; (4) cognitive readiness; (5) cognitive fatigue; (6) threat-challenge readiness; (7) skills-and-training readiness; (8) group-team readiness, and; (9) equipment readiness. This project explores both the validation of the instrument, and practical considerations for real-world implementation of the ARMS In a military population. **Methods:** In phase one, the scale was validated against objective indicators of readiness (heart rate variability and salivary cortisol) during a sleep deprivation protocol, alongside a simple cognitive performance test (psychomotor vigilance test [PVT]). Participants were 30 university students (aged 23 ± 4 y; 18 women). In phase two, the ARMS was deployed to two cohorts of Army personnel (n = 50) undergoing an 11-week training program in the Australian Army (both trainees and instructors). Participants completed the ARMS weekly, alongside the NASA Task Load Index (NASA-TLX). ARMS scores were compared with course performance metrics (course completion time) and correlated with the NASA-TLX. Participants provided qualitative feedback as to the impost, usefulness, and value of the ARMS via a survey (trainees) and focus groups (instructors). **Results:** In phase one, the ARMS responded appropriately (e.g., decrease in readiness and increase in fatigue) to sleep deprivation and scores related to changes in PVT performance and cortisol responses. In a predictive model, ARMS subscales were better predictors of cognitive performance than the physiological measures, while also being simpler to record and easier to implement for the user. In phase two, ARMS scores showed significant correlations with the NASA-TLX such that in general, increases in task load were associated with increases in cognitive and physical fatigue, and decreases in readiness (in particular physical readiness). **Conclusions:** The ARMS appears to complement and enhance the readiness monitoring capability offered by wearables and physiological measures. Practical guidelines for the implementation of the ARMS for day-to-day usage in the military will be developed. **Military Impact:** The current project has identified a candidate tool for monitoring readiness across Defence personnel and will develop guidelines that are both validated and bespoke to defence requirements.

12:30 – 12:45: Predicting alertness of military performance during cold winter training using the 2B-Alert web tool

Agustin L Folgueira [1], Nicholas Van den Berg [2], Facundo Etchehún [3], Malena Mul Fedele [4], Xavier Michaud [2], Marcela Ovejero [1], Nathalie Pattyn [5], Daniel Vigo [4], Guido Simonelli [6]

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[2]Hôpital du Sacré-Cœur de Montréal, Canada
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Purpose: Alertness is vital for soldier safety and operational success. The conventional sleep duration recommendation is not only unrealistic during military operations, but also neglects inter-individual differences in sleep quantity and wake behaviours. The 2B-Alert software predicts alertness of individuals given sleep quantity, but this has not been tested following sleep in harsh cold environments. We utilised 2B-Alert to examine alertness of soldiers undergoing military training under harsh winter conditions and assessed its reliability against the standard psychomotor vigilance task (PVT). **Methods:** Participants were Argentinian Army male volunteers (n = 24; mean age = 27.3 y) undergoing a winter mountain course. Actigraph recordings before, during, and after the winter training were obtained to quantify sleep duration. Levels of carbon dioxide, temperature, and humidity were collected during the sleep period. To compare against 2B-Alert, mean response time (ms) and number of lapses (responses ≥ 500 ms) of a 5-min PVT were collected at four intra-daily timepoints (08:00, 15:30, 19:00, and 23:00) before, during, and after the winter training. Repeated-measures ANOVAs tested performance at each stage. **Results:** 2B-Alert predictions of mean response and lapses were similar to PVT assessments (at 08:00, 15:30, and 23:00; all $p > 0.05$), except PVT mean response at 19:00 was significantly slower than 2B-Alert predictions before ($p = 0.029$) and during ($p = 0.012$) winter training. After winter training, PVT mean response was slower than 2B-Alert predictions at every time point ($p = 0.039$, $p = 0.023$, $p = 0.002$, and $p = 0.023$, respectively), whereas lapses were similar between 2B-Alert predictions and PVT performance (all $p > 0.05$). For sleeping environment, ambient measures before and after winter training were similar (temperature 21.9 ± 0.9°C, humidity 61 ± 3%, carbon dioxide 1241 ± 208 ppm). During two nights of winter training spent sleeping in snow caves, ambient measures were colder (temperature of 0.98 ± 0.2°C, $p < 0.05$), more humid (93 ± 0%, $p < 0.05$), and had more carbon dioxide 1551 ± 30 ppm, $p < 0.05$), compared with baseline levels. During winter training, mean sleep time was 6:05 ± 00:33 hh:mm and was not significantly different between before and after winter training ($p > 0.05$). **Conclusions:** 2B-Alert predictions overestimated mean response time during recovery from inadequate sleep in harsh cold environments. Impaired alertness appears to be inaccurately predicted in the context of poor sleep in extreme environments. Preventative strategies to mitigate performance impairments cannot rely on one-size-fits-all approaches to recover mental and physical military readiness and might require inter-individual adaptation. **Military Impact:** The use of fatigue risk prediction model may not be accurate at predicting soldier's cognitive

performance during and following a winter.

12:45 – 13:00: Sleep deprivation and physical fatigue: impact of cognitive load and motor performance within United States military members

Joshua Springer [1]

[1]United States Army, USA

Purpose: Military members are commonly exposed to prolonged sleep deprivation. Despite acute or prolonged sleep loss, they are expected to demonstrate high levels of physical and cognitive performance. Previous research has explored the impact of sleep on motor performance; however, few studies have explored the combined effect of sleep deprivation and physical fatigue on subsequent motor performance. Furthermore, there is a lack of research exploring how cognitive load is impacted by the combined effects of sleep deprivation and physical fatigue. The study aimed to explore the effects of sleep deprivation and physical fatigue on graded marksmanship and cognitive load in a simulated combat environment. **Methods:** Participants ($n = 10$) performed a three-part, graded rifle marksmanship task under two conditions. During each condition, participants completed a precision and accuracy task, discriminatory reaction task, and a speed and accuracy task. Additionally, participants were asked to complete a fatigue inducing event prior to completing each marksmanship task. During the first condition, participants completed the three-phase rifle marksmanship task following total sleep restriction for 24 hours. During condition two, participants completed the three-phase rifle marksmanship task following normal sleep conditions. **Results:** An ANOVA showed main effects for each marksmanship task ($p < 0.001$, $p = 0.02$, $p = 0.08$, respectively), as well as individual cognitive load measurements ($p = 0.003$, $p = 0.002$, $p < 0.001$, respectively). Post hoc testing revealed significant differences between baseline, total acute sleep deprivation, and the combination of sleep deprivation and physical fatigue ($p < 0.05$). **Conclusions:** These results support the hypothesis that the combination of total acute sleep deprivation and physical fatigue significantly decreased rifle marksmanship performance, as well as an individual's ability to evaluate their performance when compared to baseline. **Military Impact:** Further research should continue to examine the effects of sleep deprivation and fatigue, both physical and mental, and its interaction with motor performance.

13:00 – 13:15: Metabolomic profiling of acute stress events associated with 72-h military field exercises

Elizabeth Dhummakupt [1], Conor Jenkins [1], Allison Melka [2], Kenneth Racicot [3], Kari L McKenzie [3], Joseph Patterson [3], Karen R Kelly [4], John Ramsay [3], Seth Elkin-Frankston [3], Victoria G Bode [3]

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[3]US Army DEVCOM Soldier Center, USA
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Purpose: Characterisation of physiological changes that occur in a soldier during simulated combat help researchers unravel the biomolecular components that are linked to physical and cognitive performance during operations. By assessing saliva samples collected during military field exercises via untargeted metabolomic mass spectrometry, we can identify potential biomarkers of soldier performance. **Methods:** Seventy-six male members of the US Army completed a six-day field study that included a baseline day, a 72-h exercise, and two days of recovery. During the field study, saliva was collected via oral swab at specific time points that corresponded to high physical and cognitive stress events. The saliva was spun down and analysed via liquid chromatography high resolution accurate mass spectrometry (Thermo Scientific QE Plus Orbitrap), and data was analysed by multivariate statistical methods (Thermo Scientific Compound Discoverer 3.0) for significantly changing small molecules (i.e., metabolites). The initial results focus on the Tactical Stress Marksmanship Assessment (TSMA) event that took place during the field study. TSMA is a timed and scored marksmanship task that simulates tactical stress (i.e., physical and cognitive), in which soldiers are given course scoring criteria and rules of engagement (i.e., accurately engaging near-peer and asymmetric threats while sparing friendlies and maintaining movement speed). TSMA was executed twice during the field study—first on the baseline day and second on the first recovery day. One sample was collected before the event and five samples were collected immediately after the event and every 15 minutes afterward for an hour. **Results:** Over 500 high confidence (i.e., log2 fold change, $p < 0.05$) metabolites were detected, which map to over 200 biochemical pathways. Some of these pathways include: (1) purine nucleotide salvage; (2) arginine and polyamine biosynthesis; (3) L-methionine salvage, and; (4) histidine, purine, and pyrimidine biosynthesis. **Conclusions:** The purine nucleotide salvage pathway participates in many aspects of cellular metabolisms, especially the structure of DNA and RNA. Molecules in this pathway perform functions in cell signalling and generation of cellular energy. Maintaining this pathway is critical for normal function. Initial analysis of changing metabolites from a high stress event demonstrates many pathways associated with cellular energy and maintenance being highly affected. Further analysis will produce a group of metabolites that should be monitored for soldier performance. **Military Impact:** This research allows for previously undetermined biomarkers of soldier performance to be identified.

Oral Communication 13: Physical Training

Wednesday 13th September, 11:45 to 13:15

Room 3

Chair: *Heikki Kyröläinen, National Defence University, Finland*

11:45 – 12:00: Physical training and changes in physical performance and body composition of soldiers during international military operations: systematic review and meta-analysis

Kai Pihlainen [1], Matti Santtila [2], Tommi Ojanen [3], Jani P Vaara [2], Heikki Kyröläinen [4]

[1]Defence Command, Finland
[2]National Defence University, Finland
[3]Finnish Defence Research Agency, Finland
[4]University of Jyväskylä, Finland

Purpose: Occupational demands during international military operations require soldiers to maintain high levels of aerobic endurance and neuromuscular performance. The deployment duration of several months may deteriorate physical performance significantly due to decreased physical activity and / or detraining. The aim of the present review was to provide an overview of physical training and changes in body composition and physical performance during prolonged (≥ 3 months) military operations. **Methods:** Systematic review and meta-analysis applied PRISMA guidelines with PICOS format. Relative changes from the within-group pre-post-deployment results were calculated to enable comparison between the studies. Thereafter, effect sizes (ES) with 95% confidence intervals (CI) were calculated. **Results:** Twenty-six studies out of the screened 4,060 records met the inclusion criteria. Large inter-individual variations were observed in physical training volume as well as decrements, especially, in endurance training frequency and volume. A reduction in total training load was often associated with negative changes in body composition and physical performance according to the principle of training specificity. A decrease in aerobic fitness was the most consistent finding in the available 10 studies (Hedge´s g [g] = 0.22, 95% CI = 0.00 to 0.44). Maximal strength of the lower and upper body was reported in eight studies with small overall increases (g = –0.33, 95% CI = –0.50 to –0.16 and g = –0.33, 95% CI = –0.19 to –0.46, respectively). The overall ESs for improved push-up and sit-up performances were small (g = –0.34, 95% CI = –0.52 to –0.15 and g = –0.26, 95% CI = –0.44 to –0.07, respectively). The Ess for changes in fat mass (g = 0.05, 95% CI = –0.10 to 0.21) and muscle mass (g = –0.04, 95% CI = –0.20 to 0.12) were trivial. **Conclusions:** Aerobic capacity was the only physical performance variable of which mean value decreased during deployments. The Ess of all studied variables were mainly trivial, showing that the mean changes during operations were small. Changes in body composition and physical performance are likely explained by individual variation in training status and the implementations of training during deployments. Individuals with higher initial fitness level were more susceptible to decrements in their physical performance during operation. Therefore, it is challenging to provide universal training recommendations suitable for all soldiers. **Military Impact:** Each deployment is a unique challenge for soldiers to maintain their initial fitness level and body composition, which requires individually tailored training programs for optimisation of physical performance and readiness throughout the operation. Soldiers should be encouraged to maintain frequent strength and endurance training at the activity level preceding the operation.

12:00 – 12:15: The physical demands of British Army Infantry basic training: An observational study

Alex J Rawcliffe [1], Shaun Chapman [1], Kimberley Jacka [1], Mastveer Ghatahora [1], Ellie Liddell [1], Lauren E Martin [1], Andrew J Roberts [1]

[1]Army Recruit Health and Performance Research, UK

Purpose: The Combat Infantry Course aims to produce battle-ready soldiers and is considered one of the most physically demanding courses in the British Army. Standard line infantry basic training (BT) involves a blended syllabus of generic military preparation and regimental specific soldiering skills, however, is characterised by high injury rates and training drop out, likely caused, in part, by the high physiological strain of training. The aim was to evaluate the physical demands of line infantry BT to support the development and/or modification of training policy/practice relative to health and performance. **Methods:** Full data sets from 52 infantry recruits across 12-weeks of BT were used for analyses. Participants completed a weekly online workload and sleep questionnaire and wore an activity (Garmin) and sleep (Actigraph) watch each day/night of BT, measuring distance (daily/weekly, km), heart rate during the day and sleep indices at night, respectively. Activity and sleep data were extracted directly from the watches and subsequently cleaned/processed using a custom R script and proprietary software (Actilife), respectively. Daily/weekly distance was reported descriptively. Questionnaire data was extracted from LimeSurvey and analysed descriptively. A repeated-measures ANOVA was used to determine differences in total sleep time between BT weeks. **Results:** The average daily distance was 16.9 ± 8.8km across BT. Average weekly distances differed between BT weeks, with the highest occurring in weeks 2 (99.2 ± 53.0 km), 3 (125.2 ± 51.6 km), 8 (100.6 ± 34.0 km), and 10 (93.6 ± 22.1 km) of BT. Average weekly distances between weeks 1 and 3 remained ≥ 91km. Total sleep time was significantly lower in week 1 (05:22 ± 00:43 hh:mm) compared with the majority of BT weeks ($p \leq 0.003$). The greatest total sleep time was observed in week 8 (06:36 ± 01:27 hh:mm), with an average total sleep time of 05:55 ± 00:45 hh:mm across BT. Perceived mental and physical workload ranged from “somewhat high” to “high” across BT, with the greatest perceived demand observed in weeks 2 and 5 of BT for both mental and physical workload. **Conclusions:** The high distances observed throughout BT, combined with poor overall sleep duration explains, in part, the high levels of perceived mental and physical workload reported during BT. The high distances observed during BT may contribute to high injury rates observed during the initial weeks of BT. **Military Impact:** Routine evaluation of the physical and mental demands of BT is required to support the development and design of subsequent BT courses.

12:15 – 12:30: Body composition and performance adaptations of British Army Infantry basic training: an observational study

Andrew J Roberts [1], Lauren E Martin [1], Shaun Chapman [1], Kimberley Jacka [1], Mastveer Ghatahora [1], Ellie Liddell [1], Alex J Rawcliffe [1]

[1]Army Recruit Health and Performance Research, UK

Purpose: The Combat Infantry Course aims to produce battle-ready soldiers. It is considered one of the most physically demanding courses in the British Army and is characterised by high injury rates. The standard line infantry basic training (BT) programme was recently revised with a greater focus on interval training, muscular endurance, and strength and conditioning, with reductions in running / marching activities. High aerobic fitness, fat-free mass, muscle strength, and percentage body fat are key characteristics shown to mitigate injury risk and enhance performance ability of key physical BT activities. The aim was to evaluate changes in body composition and physical performance following the revised standard line infantry BT course. **Methods:** 136 male infantry recruits agreed to participate at the start of BT. Whole-body dual energy X-ray absorptiometry scans were conducted in weeks 1, 6, and 12 measuring fat mass, fat-free mass, and bone mineral density and content (72 full datasets). Role fitness test (2 km run, mid-thigh pull, medicine-ball throw) scores were collected in weeks 1 and 12 to determine changes in physical performance (52 full datasets). Body mass index (BMI) was also calculated. A repeated measures ANOVA and paired-samples t-test was used to determine changes in body composition (weeks 1, 6, 12) and physical performance (weeks 1, 12), respectively. **Results:** Fat mass reduced by week 6 (3.7%) and 12 (19%) from week 1 ($p < 0.02$). Similar increases (by mass) in fat-free mass also occurred in week 6 (0.3%, $p > 0.05$) and 12 (3.5%, $p < 0.001$). There were minimal changes in recruits body mass (< 0.1 kg) or BMI (< 0.1 kg·m-2) throughout the course ($p > 0.05$). Changes in bone mineral content (< 17 g) and density (< 0.1g·cm-2) were all small ($p > 0.05$). Recruits improved mean 2 km run time by 52.4 ± 39.9s and medicine-ball throw distance by 21.1 ± 41.7 cm ($p < 0.001$). Mid-thigh pull performance reduced by 28.2 ± 53.8 kg on average ($p < 0.001$). **Conclusions:** Recruits fat mass reduced, with similar gains in fat-free mass resulting in minimal changes in overall body mass. While positive improvements occurred in run time and throw distance, the reduction in output during the mid-thigh pull implies the strength training component requires further investigation. A low resistance training stimulus may also explain the limited bone changes. Optimising muscle mass and bone strength changes during BT are likely to both enhance performance and reduce injury risk. **Military Impact:** Routine evaluation of the physical demands and adaptations of BT is required to support the development and design of subsequent BT courses to optimise health and performance of standard line infantry recruits.

12:30 – 12:45: Monitoring personnel responses to military training: a synthesis of research findings

Luana Main [1], Sean Corrigan [1], Jamie Tait [1], Sean Bulmer [1], Jace Drain [2]

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Purpose: Military personnel are at risk of injury and negative long-term health outcomes across their career if workload is not appropriately overseen throughout a military career. Implications of sustained allostasis include increased risk of illness and injury and decreased occupational performance and readiness. In non-military contexts (e.g., athletes), a range of subjective and objective measures have been used to monitor adaptation, optimise performance potential, and inform training programme design. The aim of this research was to assess the utility of these same measures in two different military training environments to monitor personnel responses to training. **Methods:** The first data collection activity was at the Australian Army Recruit Training Centre where recruits (n = 48; 39 men and 9 women; aged 24.5 ± 7.0 y; body mass: 76.1 ± 14.9 kg, height: 1.76 ± 0.1 m; and body mass index; 24.4 ± 3.4 kg·m2) were monitored for the 12-week basic training course. The second 16-day data collection activity was across the final capstone assessment within the Combat Engineer trade-specific training course. Sixty-two soldiers completing their initial employment training consented to participate in the study (59 men and 3 women; aged 21.9 ± 4.6 y; body mass: 82.8 ± 12.1 kg, height: 1.79 ± 0.1 m; and body mass index; 25.9 ± 3.4 kg·m2). In both instances, a suite of objective and subjective measures were collected, including actigraphy for measures of physical activity and sleep, heart rate variability (HRV), subjective wellbeing, and the circulating biomarkers testosterone, cortisol, and measures of inflammation. **Results:** Self-reported measures were sensitive to fluctuations in training demands ($p < 0.05$). Overnight HRV was sensitive to periods of allostasis ($p < 0.05$) and demonstrated a quicker rate of recovery in combat engineer training than self-reported measures. Simple cognitive performance (e.g., vigilance attention) measures were compromised when exposed to sleep deprivation, with a small provision of sleep providing some performance restoration. **Conclusions:** Subjective measures of training stress appear to offer utility for personnel management decisions. Particularly in conjunction with other objective measures such as overnight HRV and performance on a simple to administer reaction time test. Hormone responses may serve as surrogate markers of physiological strain. However, currently the technology is not available to support this in a cost effective, scalable way. **Military Impact:** Subjective measures appear to have the most utility given the low burden (e.g., time, cost, technology). In future, a suite of biomarkers could be used to serially monitor recruit adaptation to the training stimulus and may also be used to indicate risk of injury or attrition.

12:45 – 13:00: A comparison of performance on role-related fitness tests between British Army recruits and in-service soldiers

Carla Rue [1], Sarah Needham-Beck [1], Tessa Maroni [1], Kimberly Ashdown [1], Ben Lee [1], Faye Walker [1], Josh Osofa [1], Julianne Doherty [1], Christopher Vine [1], Sophie L Wardle [2], Julie P Greeves [2], Paul Saunders [2], Anne Fieldhouse [2], Sam D Blacker [1], Steve Myers [1]

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Purpose: British Army basic training (BT) and initial trade training (ITT) enable personnel to develop role-related physical capability to perform their job-roles. The aim of this study was to compare the physical performance of separate cohorts of recruits in ITT (who had completed BT) and in-service soldiers, on a series of gym-based fitness tests and role-related representative military tasks (RMTs). **Methods:** 316 British Army personnel (68 recruits [63 men, 5 women: 22 ± 3 y, 71.6 ± 8.4 kg, 1.74 ± 0.07 m], 248 in-service [225 men, 23 women: 27 ± 6 y, 78.7 ± 12.7 kg, 1.76 ± 0.08 m]) completed two sessions separated by minimum of 48 h. Session 1; body mass, stature, age, and seven gym-based tests (2-km run, broad jump, seated medicine ball

throw, hex bar deadlift, 100-m shuttle sprints, pull-ups, and isometric mid-thigh pull). Session 2; seven RMTs (load carriage [Stage 1: A = 4 km, 35-40 kg, 4.8 $km.h^{-1}$, Stage 2: 2 km, 20-25 kg, both to individual timed best effort], tactical movement, water can carry, casualty drag, vertical lift, incremental lift and repeated carry). Independent sample student t-tests and Welch t-tests were employed with effect sizes reported as Cohen's d to examine group differences. **Results:** In-service soldiers were ≈5 years older ($p < 0.001$, $d = 1.022$), heavier ($p < 0.001$, $d = 0.653$), and scored higher on the broad jump ($p = 0.024$, $d = 0.312$) and seated MBT ($p = 0.007$, $d = 0.370$), but were slower on the 2-km run ($p = 0.047$, $d = 0.282$), load carriage ($p = 0.019$, $d = 0.360$), tactical movement ($p = 0.001$, $d = 0.476$), and casualty drag ($p = 0.001$, $d = 0.656$) compared with recruits. No other differences were observed between in-service soldiers and recruits. **Conclusions:** This study demonstrates differences in gym-based fitness test and RMT performance between recruits and in-service soldiers. Recruits could perform the role-related RMTs, which suggests that BT provides a sufficient training stimulus. **Military Impact:** Performance on the gym-based tests and RMTs with the highest aerobic and anaerobic requirement were typically best performed by recruits, suggesting either BT effectively developed these components of fitness, or they decline through a soldier's career. In contrast, the higher performance on broad jump and seated MBT for in-service soldiers compared with recruits indicate muscle power develops during a service career following BT and ITT. In future these findings could inform development and management of role-related physical fitness during BT, ITT, and through career.

13:00 – 13:15: Physical employment standards next steps: informing the development of a concept for a role-related fitness continuum

Sam D Blacker [1], Tessa Maroni [1], Kimberly Ashdown [1], Faye Walker [1], Barry Alexander [2], Julie Draper [2], Steve Myers [1]

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Purpose: Physical employment standards (PES) measure the minimum role-related physical capability required to perform job-roles. The British Army in-service PES, Role Fitness Test (Soldier) [RFT(S)], balances fidelity and feasibility to replicate the physical demands of British Army job roles, while being conducted in a four-hour period at any location. There may be points in a military career, such as physically demanding courses or deployments conducted over days to weeks where the cumulative demands may be above the minimum PES. This study aimed to quantify the physical demands of the Section Commanders Battle Courses and British Army Platoon Sergeants (SCBC and PSBC) from which a concept for a role-related fitness continuum underpinned by PES was developed. **Methods:** Eighteen male junior (age 27 ± 3 y, body mass [BM] 85.4 ± 14.9 kg, height 180 ± 9 cm), and 20 male senior (age 31 ± 3 y, BM 89.1 ± 14.9 kg, height 182 ± 7 cm) non-commissioned infantry Soldiers were monitored across the 8-week tactics phase of SCBC and PSBC. Best effort 2 km loaded march time and BM were measured on course entry, with BM also measured on completion. Participants physical activity level (PAL) and energy expenditure (EE) were quantified throughout the course using a wrist-worn tri-axial accelerometer. Course data were compared using independent sample t-tests. An

ergonomic analysis was conducted to document the physically demanding tasks performed on the courses. **Results:** Loaded march time was similar between courses (SCBC = 11.80 ± 1.02 vs PSBC = 11.54 ± 0.87 min; $p > 0.05$). Daily EE was similar between courses (SCBC = 16.9 ± 2.5 vs PSBC = 16.2 ± 2.2 $MJ \cdot d^{-1}$; $p > 0.05$), but daily PAL was slightly higher for SCBC than PSBC (2.2 vs 2.1; $p = 0.04$). BM decreased over the courses (SCBC = –3.9 ± 2.9 kg, PSBC = –2.0 ± 2.7 kg, $p > 0.05$). The ergonomic analysis demonstrated that the physically demanding tasks performed on the courses matched those identified in the PES job task analysis. **Conclusions:** The accelerometery data showed the courses were arduous, indicating candidates need to commence courses physically prepared. The courses require candidates to complete the range of job tasks identified in the PES research. The cumulative total time spent physically active on the courses and some individual task durations exceed those experienced in RFT(S). **Military Impact:** Data from this study informed the development of a role-related fitness continuum concept where PES provides a minimum physical fitness benchmark. On this continuum, during arduous activity, bespoke physical tests and structured physical training can be used to support personnel to develop and maintain the physical capability to perform their job-roles.

Posters 2: Musculoskeletal Injury and Physiology

Wednesday 13th September, 11:45 to 13:15

Board 1: Bone formation and resorption biomarkers are not associated with stress fracture risk during U.S. Army Basic Combat Training

Jeffery S Staab [1], Kathryn M Taylor [1], Ian M Hussian [1], Janet E Staab [1], Laura J Lutz [1], Alyssa V Geddis [1], Marinaliz C Reynoso [1], Cara E Sczuroski [1], James P McClung [1], Erin Gaffney-Stomberg [2], Kristin L Popp [1], Mary L Bouxsein [3], Leila A Walker [1], Katelyn I Guerriere [1], Stephen A Foulis [1], Julie M Hughes [1]

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Purpose: Biomarkers of bone formation and resorption did not predict stress fracture risk in a small cohort of male Israeli Army trainees. This study expanded upon that work and examined if the same biomarkers measured at the start of U.S. Army Basic Combat Training (BCT) predicted stress fracture risk in a large cohort of both male and female trainees. **Methods:** Fasted, morning blood samples were collected on 1087 (771 males, 316 females) trainees at the start of BCT. Biomarkers of bone formation (P1NP and BAP), bone resorption (CTX and TRAP5b), and 25OHD were measured in serum. Participants were stratified into tertiles for each biomarker. Stress fractures were identified from trainee medical records. Stress fracture incidence for Low and High tertiles were compared to the Middle tertile and the odds ratio (OR) was calculated using multivariable logistic regression with adjustments for age, sex, race, and serum 25OHD. **Results:** Overall stress fracture incidence was 5.2% with sex-specific incidences of 10.4% in females (n = 33) and 3.1% in males (n = 24). Low, Middle, and High tertile stress fracture incidences for BAP were 4.75%, 4.93%, and 6.04%, respectively, for P1NP were 5.31%, 5.00%, and 5.42%, respectively, for TRAP5b were 7.26%, 5.00%, and 3.52%, respectively, and for CTX were 6.98%, 5.26%, and 3.53%, respectively. After adjustment for covariates, there were no significant OR [95% CI] for Low and High tertiles compared with Middle for BAP (Low: 0.73 [0.36-1.49], p = 0.391; High: 1.99 [0.99-3.97], p = 0.052), P1NP (Low: 0.72 [0.35-1.45], p = 0.353; High: 1.59 [0.80-3.18], p = 0.190), TRAP5b (Low: 1.12 [0.58-2.17], p = 0.727; High: 0.90 [0.43-1.91], p = 0.790), CTX (Low: 0.79 [0.40-1.56], p = 0.498; High: 1.02 [0.48-2.19], p = 0.954). **Conclusions:** In our cohort, biomarkers of bone formation and resorption at the start of BCT were not associated with stress fracture risk during training. **Military Impact:** Measuring biomarkers of bone formation and resorption at the start of BCT is an ineffective means for identifying trainees at risk for stress fracture during BCT. Disclaimer: The opinions or assertions contained herein are the private views of the author(s) and are not to be construed as official or as reflecting the views of the Army, the Department of Defense, or the U.S. Government.

Board 2: Qualitative exploration of US Reserve Officers' Training Corps trainees' reasons for injury concealment

Joshua Wooldridge [1], Tricia Kasamatsu [2], Brian Schilling [3], Danny Young [3], Kara Radzak [3]

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[2]California State University – Fullerton, USA

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Purpose: While musculoskeletal injuries (MSKIs) are a leading threat to military readiness, service members' unwillingness to seek care constrains current prevention and surveillance efforts. A growing body of evidence shows US service members conceal a large proportion of injuries, especially in training environments. Trainees in the US Reserve Officers' Training Corps (ROTC) conceal ~66% of MSKIs—the highest of any population measured to date. This qualitative study sought to identify perceptions, beliefs, and attitudes of ROTC trainees that influence MSKI reporting and concealment behaviours. **Methods:** This study used Consensual Qualitative Research methodology. US Army, Air Force, and Naval ROTC trainees participated in semi-structured interviews comprising ten open-ended questions. Two researchers separately analysed and inductively coded interview transcripts. Then, they combined the two analyses into a unified codebook, which was used to recode transcripts deductively. The two coders and an auditor developed a final, consensus-based analysis, from which they identified emergent domains. **Results:** Eleven ROTC trainees (six Army, three Air Force, and two Naval; five women and six men) completed interviews for analysis. Four major domains emerged from participants' response data: perceptions of MSKIs in the military and ROTC, reasons for reporting injuries, reasons for concealing injuries, and proposed methods to improve reporting behaviours in trainees. ROTC trainees perceived injury reporting and the state of being injured as stigmatised, despite their awareness of MSKI prevalence. Trainees described only reporting injuries when severity hindered physical performance or made the injury difficult to conceal. Access to, and knowledge of, available health care influenced both reporting and concealment. Primarily, fear of social and career repercussions, along with a lack of healthcare access, drove trainees to conceal injuries. To improve reporting, ROTC trainees desired changes to the ROTC's organisational culture and operational standards and procedures. Culturally, trainees desired increased acceptance and support for injured trainees, and decreased trivialisation of the MSKI threat. Suggested operational changes to the ROTC included integrated health care, local injury surveillance and reporting systems, optimised physical training, and adding an injury-related educational curriculum. **Conclusions:** ROTC trainees perceive military culture as one which trivialises the threat of MSKIs and stigmatises those who are injured. Thereby, trainees' fears of social and career repercussions become barriers to injury reporting. **Military Impact:** Addressing trainees' injury concealment could improve service members' health and military readiness and increase injury surveillance accuracy. To mitigate concealment, behavioural antecedents of reporting, such as perceptions and beliefs, must be identified and targeted for intervention.

Board 3: Effect of Army Combat Fitness Test training on low back pain in US Army basic combat trainees

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Purpose: Recent analyses found that 35% of active-duty service members and 30% of basic combat trainees reported low back pain (LBP). The Army Combat Fitness Test (ACFT), a six-event test, was implemented to improve physical fitness and decrease injury risk. We hypothesised that training for the ACFT may reduce injury risk, specifically LBP, since deadlifting increases trunk and hip extensor strength. This study compared the prevalence of LBP in Basic Combat Training (BCT) before and after the implementation of the ACFT. **Methods:** Study participants were recruited and divided into two groups to represent pre-ACFT policy (2019; n = 1075; female = 438, male = 637), and post-ACFT policy in (Oct 2021 to 2022; n = 369; female = 166; male = 203). Body composition was measured using dual-energy X-ray absorptiometry at the beginning of BCT. LBP diagnoses were extracted from medical records during BCT. A logistic regression model was used to compare pre- and post-ACFT policy groups and sex, while adjusting for sex and lean body mass. A chi-square test was used to compare LBP frequency in non-parametric variables of ACFT group and sex. **Results:** There were no differences by group in age, body mass index, or % body fat (all $p > 0.05$) between groups. There were differences between groups for lean body mass (mean ± SD; pre-ACFT = 50.2 ± 10.8 kg, post-ACFT = 51.6 ± 11.2 kg; $p = 0.02$). Prevalence for LBP in both pre- and post-ACFT groups was 7.6% (82/1075 and 28/368, respectively), with odds ratio of 0.97 (95% CI: 0.62 – 1.52; $p = 0.88$). Prevalence for LBP in the total population was 10.4% for females compared with 5.6% for males, with odds ratio of 2.2 (95% CI: 1.21 – 4.51; $p = 0.01$). **Conclusions:** No differences were seen in the prevalence of LBP between groups, which indicates training for the ACFT may not have a meaningful effect on prevalence of LBP. Further, the higher prevalence of LBP in females compared with males is consistent with prior research and likely not attributable to the ACFT. **Military Impact:** Although training for the ACFT may improve some metrics of military readiness, it does not appear to reduce LBP during BCT. **Disclaimer:** The views expressed in this abstract are those of the authors and do not reflect the official policy of the Department of Defense.

Board 4: Identifying risk factors is imperative in reducing the costly burden on neck pain in fast jet aircrew: preliminary analyses of a two-year prospective study

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Purpose: Fast jet aircrew (FJA) suffer higher rates of musculoskeletal complaint episodes (MCE, i.e., injuries) of the neck, which impacts operational capability. Very few studies have conducted prospective studies to identify potential risk factors. The purpose of this study was to investigate risk factors for neck MCE in Royal Australian Air Force (RAAF) FJA. **Methods:** 306 RAAF FJA flying five airframes (Hawk-127, F/A-18, F/A-18F, EA/18-G, F-35) were monitored over two-years (4 × 5-month capture periods). MCEs were captured weekly using the validated self-reported University of Canberra Fast Jet Aircrew Musculoskeletal Questionnaire (UC-FJAMQ). Potential risk factors included: demographics, flying history, previous injury, worry of future injury, anthropometry, neck / trunk strength and range-of-motion (ROM), gym-based strength

testing (squat, deadlift, bench press), rowing ergometer aerobic / anaerobic capacity, and flying rates. Generalised estimating equations were used to evaluate risk associations between these variables and experience of MCE. **Results:** Each reporting period included a mean of 228.3 FJA. Mean weekly UC-FJAMQ response rate was 62%. 414 neck new MCEs were recorded. Due to the large number of variables, they were analysed in sets to minimise type-II error. Variables found to significantly increase risk of neck MCE included: being female (OR [95% CI], 2.6 [1.3, 5.0]), previous neck pain (ever: OR 1.8 [1.1, 2.9], previous 12-months: OR 3.0 [2.0, 4.6], previous 3-months: OR 3.7 [2.1, 6.7]), worry of future injury (Expß [95% CI], 1.2 [1.1, 1.3]), and flying more sorties (Expß 1.3 [1.1, 1.6]) and hours (Expß 1.2, [1.0, 1.3]) per week. Exposures found to significantly decrease risk included: being taller (Expß 0.96 [0.93, 0.99]), and greater neck lateral flexion ROM (Expß 0.97 [0.95, 0.99]). Neck / trunk strength, gym-based strength, and rowing ergometer aerobic/anaerobic capacity, did not influence MCE risk. **Conclusions:** Preventing first episodes of neck injury in FJA should be prioritised, given previous injury and worry of future injury were strongly associated with risk. Unfortunately, few modifiable factors appeared to influence risk. Given strength capacity as measured in this study did not contribute to risk of neck injury, the mechanisms for any potential benefit from strengthening programs need further investigation. **Military Impact:** This is the first prospective study conducted with a large group of FJA over an extended time period that captured and analysed a broad array of exposures combined with a validated surveillance tool. Time-poor FJA can reconsider their need to undertake time-consuming regular strength testing that is used to inform neck injury risk. Exercise programs that increase individual FJA confidence, and thus reduce worry of future injury, should be of greater focus than those targeting increased strength alone.

Board 5: Biopsychosocial factors associated with musculoskeletal injury in Marine Corps Officers differ between males and females

Sarah J de la Motte [1], Emily A Ricker [1], Amelia S Barrett [1], Carl W Goforth [2]

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Purpose: Biopsychosocial effects on musculoskeletal injury (MSK-I) based on sex is not understood. Our goal is to describe relationships between biopsychosocial factors and documented MSK-I in male and female officers during Marine Basic Officer Course (BOC) training. **Methods:** At BOC entry, consented officers (female: 197, male: 1477) completed: demographics, movement screening, Healthy Eating Score-5, Patient Health Questionnaire-15 (PHQ-15), Generalised Anxiety Disorder-7, Patient Health Questionnaire-8, Perceived Stress Scale, Eating Disorder Examination Questionnaire-Short, Situational Motivation Scale, Brief-COPE, Connor-Davidson Resilience Scale, Short Grit Scale, Maslach Burnout Inventory (modified), Deployment Risk and Resilience Inventory (DRRI)-2: Unit Social Support (modified), DRRI-2: Support from Family and Friends (modified), DRRI-2: General Harassment (modified), Insomnia Severity Index-Short, Fatigue Rating, Epworth Sleepiness Scale, Pittsburgh Insomnia Rating Scale-2, Stigmatizing Situations Inventory (modified), and Tests of Performance Strategies. Medically documented MSK-I during BOC was tracked. Because our sample was

~12% female, and females sustained higher MSK-I rates, separate sex-specific Boruta variable reduction and binary logistic regression models were run. For each, variables selected during variable reduction were combined with known MSK-I risk factors and modelled in logistic regressions. **Results:** A greater percentage of female compared with male officers sustained MSK-I during BOC (57% *vs* 33%, $p < 0.001$). For female officers, nine independent variables were identified; three were significant. Compared to younger female officers, females aged 23.8 to 25.9 y had lower MSK-I odds (OR [95% CI], 0.07 [0.01, 0.40], $p = 0.005$). Females with self-reported current MSK pain or MSK-I at entry had greater odds of MSK-I (6.58 [1.69, 34.71], $p = 0.012$). Increased Maslach Burnout Inventory scores were associated with lower MSK-I odds (0.76 [0.59, 0.94], $p = 0.017$). For males, 15 independent variables were identified; four were significant. PHQ-15 somatic symptoms were related to increased MSK-I odds (1.16 [1.06, 1.27], $p = 0.001$). Depressive symptoms were negatively related to MSK-I (0.92 [0.86, 0.99], $p = 0.021$). Males who self-reported current MSK pain or MSK-I at entry had greater MSK-I odds (1.68 [1.01, 2.79], $p = 0.046$). Compared with males who dropped, on-time graduates had lower MSK-I odds (0.43 [0.29, 0.65], $p < 0.001$). **Conclusions:** Using variable reduction, MSK-I risk factors differed by sex, resulting in models with different independent variables for each. For both sexes, self-reporting current MSK pain or MSK-I at entry increased MSK-I odds. **Military Impact:** Distinct biopsychosocial factors were associated with documented MSK-I in male and female Marine BOC officers. We recommend other military researchers consider sex-specific MSK-I modelling.

Board 6: Screening to predict risk of injury in tactical athletes (SPRINT): a scoping review

David M Boland [1], Robert A Briggs [2], Stephen A Gay [1], Emily C Eugenio [2], Matthew J Corbitt [1]

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Purpose: Due to the physical demands of their profession, military personnel and other tactical athletes regularly participate in activities associated with increased risk of musculoskeletal injury (MSKI). Recent trends, such as the Holistic Health and Fitness initiative of the US Army, embed fitness professionals and rehabilitation experts directly into operational units to perform injury prevention and human performance optimisation roles. This scoping review aimed to identify the most promising tools currently used to screen human movement in athletic populations to stratify injury risk, which hold potential for use by military providers working with tactical athletes. **Methods:** A preliminary search was made to identify key words and develop a comprehensive search strategy. A scoping review was then conducted in three databases (PubMed, CINAHL, and SPORTDiscus) and gray literature to identify primary and secondary research reporting on the use of movement screens to predict risk of musculoskeletal injury. Selection and categorisation of included studies were performed by two independent reviewers and discrepancies were settled by a third reviewer. Articles were included if they were published in English, included athletic populations, and reported predictive or diagnostic statistics regarding the screen's ability to identify injury risk. **Results:** A total of 73 articles were identified for inclusion in this scoping review. The Functional Movement Screen (FMS) was the most widely represented, being independently reported in 46% of studies, followed by

the Y-Balance Test (YBT) or Star Excursion Balance Test (SEBT) (15%), and Landing Error Scoring System (LESS) (7%). The remaining 32% of articles reported on less common screening techniques, portions of these screens, or combined other predictive metrics (such as BMI or specific muscle strength testing) with screening data. **Conclusions:** The FMS and YBT / SEBT are the most commonly studied screens to assess general injury risk. Many other approaches exist, including region- or sport-specific screens, which could further inform injury prediction and injury prevention efforts in the future. **Military Impact:** The results of this scoping review help fitness and rehabilitation professionals working with military populations of tactical athletes identify movement screens with potential for implementation in injury prevention and human performance optimisation initiatives.

Board 7: U.S. Army Reserve Command Holistic Health and Fitness Pilot evaluation

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Purpose: The U.S. Army's Holistic Health and Fitness (H2F) program consists of five domains: physical readiness, nutritional readiness, mental readiness, spiritual readiness, and sleep readiness. This presentation summarises data on injuries, physical fitness, body composition, and other health factors for U.S. Army Reserve Command (USARC) soldiers participating in the baseline phase of a H2F Pilot Program. **Methods:** Twenty-one USARC units are participating in the Pilot, with each unit assigned to one of three implementation groups: 1) maximum intervention including in-person education modules and app-based physical training guidance; 2) moderate intervention with fewer resources; and 3) no intervention. Surveys were administered to participating units in late 2021 to collect baseline data on recent injuries, fitness, obesity, and health behaviours. Data were linked to medical records and Army Combat Fitness Test performance. Descriptive statistics were calculated to characterize the health status of Reserve Command (RC) soldiers. Multivariable regression was used to identify risk factors for injuries, obesity, and factors associated with passing the ACFT. **Results:** Among 2,095 baseline survey respondents, more than a quarter (28%) of men and over one third (35%) of women reported at least one injury in the previous 12 months. Injuries were most often strains (19%) and sprains (12%), involved the lower back (21%) and knees (19%), and were associated with running (22%) and weightlifting (18%). Significant baseline risk factors for injury among men identified by multivariable analysis were age ≥ 35 y, BMI ≥ 27.5 $kg \cdot m^{-2}$, moderate weekly exercise, no sprint training, and ≤ 5 $h \cdot night^{-1}$ sleep. Injury risk factors among women were age ≥ 35 years, BMI ≥ 30 kg·m-2, and moderate/high perceived stress. More than one-quarter (27%) of men and 17% of women were obese; factors associated with obesity included older age and slower times on the ACFT 2-mile run. Among RC soldiers who took the ACFT as of December 2021, 69% passed; factors associated with passing included BMI < 27.5 $kg \cdot m^{-2}$ and participation in physical training. Results during the follow-up phase (2023) will be collected and compared with baseline (2021) for all three implementation groups to quantify the impacts of the Pilot program. **Conclusions:** Injuries and risk factors in this Reserve population are similar to

those reported in other military populations, despite differing exposures. Recommendations to improve modifiable risk factors such as BMI, physical training, and sleep will be emphasised, after consideration of future multivariable analysis results. **Military Impact:** Results will inform future USARC Holistic Health and Fitness policy and implementation.

Board 8: Differences in injuries during road marching among male and female U.S. Army soldiers

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Purpose: Road marching is an essential element of military physical training that can result in injury. This study compared road marching injuries among men and women in a large population of U.S. Army soldiers. **Methods:** Injuries occurring during the previous 12 months were collected by survey for 4,238 male soldiers and 960 female soldiers, as part of baseline data collection for a larger project investigating physical training programs and injury risk. Road marching-related injuries were identified by cause reported in surveys. Two-sample t-tests were used to compare injury-related factors by sex. Road marching-related injury types and injured body regions were summarised by sex. Relative risk of road marching-related injury among women compared with men was calculated. **Results:** Women were shorter, had higher body fat, lower aerobic performance, and carried a greater proportion of their weight during road marching compared with men ($p < 0.05$). Men reported greater physical training time, marching loads, and more tobacco use ($p < 0.05$). Overall, 111 road marching-related injuries were reported (n = 91 injuries among men [4% of injuries], n = 20 injuries among women [3% of injuries]). Injuries to the lower extremities were common during road marching for both sexes, but the rate of hip injuries attributed to road marching was six times higher among women (12 per 1,000 women vs 2 per 1,000 men, $p < 0.01$). Road marching injuries also resulted in more limited duty days for women (mean ± SD, 44 ± 46 days for women, 36 ± 43 days for men). **Conclusions:** Observed differences in injury-related factors among male and female soldiers (e.g., body fat, tobacco use, fitness, physical training, and weight carried during road marching) suggest that these factors contributed to differing distributions of injuries during road marching. Recommendations suggested by previous research to carry less than 30% body weight during road marching should be followed, especially for soldiers of smaller stature as they are more likely to experience gait adaptations and physiologic effects that increase risk of lower extremity injuries. Load carriage weights relative to lean body weight should be considered in future studies. **Military Impact:** As road marching is a common soldiering task and women comprise 15% of the U.S. Army population, understanding differences in road marching-related injuries and injury risks between sexes is imperative to better inform injury prevention strategies for all soldiers.

Board 9: Effects of different load carriage systems on LEAP performance, mobility, and perceived comfort in male and female police officers

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Purpose: Dutch police officers report a high incidence of musculoskeletal injuries, with low back pain being the most reported condition. The cause of musculoskeletal injury is associated with carrying heavy equipment using the required duty belt. This study investigated the effects of alternative strategies for carrying police equipment on physical performance, comfort, and mobility during range of motion tests and a slightly modified version of the military Load Effects Assessment Program (LEAP) obstacle course. **Methods:** Twenty-two police officers (ten women) tested the standard and two alternative load carriage systems in: 1) the LEAP obstacle course adapted to police conditions, and 2) three range of motion tests: trunk lateroflexion, arm cross reach, and sit and reach. The investigated load carriage systems were: 1) standard configuration with duty belt, 2) vest and thigh holster, and 3) rucksack and flexible belt. The three carriage configurations were compared using a balanced repeated-measures design. In addition, subjective experiences regarding mobility, wearing comfort, robustness, load distribution, physical load, movement speed, hindrance, sitting comfort, and perceived exertion during LEAP were rated on 6-point Likert scales and the Borg scale. **Results:** Total LEAP time was significantly longer (mean ± SD) with the vest (285.28 ± 41.09 s) and rucksack (286.57 ± 41.33 s) configurations than with the standard configuration (278.99 ± 39.92 s; $p < 0.05$). Analyses on the separate obstacles revealed significant faster performances with the standard configuration on the agility run and when adopting shooting positions. No significant differences were found between configurations for any of the range of motion tests. Regarding subjective experiences, significant differences were only found for robustness (median [IQR]), with higher ratings (i.e., more robust) for the standard (4, [4, 5]) and vest (4, [3, 5]) configurations compared to the rucksack configuration (3, [2, 4], $p < 0.05$). Notably, 50% of both the women and men selected the vest as their preferred configuration. **Conclusions:** The differences between carriage configurations are small in terms of effect on physical performance (on average 6 to 8 s slower on LEAP) and may be explained by differences in familiarity with the systems. Effects of different carriage configurations on the incidence of musculoskeletal injuries should be investigated in a longitudinal study. **Military Impact:** This study shows that the LEAP can easily be adapted to target groups other than the dismounted soldier, broadening the possible applications of the LEAP as an evaluation platform.

Board 10: Association between self-reported injury history, physical complaints, and medical attention injury during Army basic military training

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Purpose: Effective and easily implementable methods to reduce the incidence and burden of injury during Army basic military training (BMT) are desirable. This study therefore investigated: (1) the association between prior injury history and medical attention (MA) injury; and (2) the association and accuracy of daily self-reported physical complaints on the incidence of MA injury during Army BMT. **Methods:** Recruits (n = 625, male = 524 and female = 101; age: 22 ± 6 y [range: 17 to 55 y]) completed a 12-month prior injury history questionnaire during week-one. Daily physical complaints were captured during BMT using a modified Oslo Sports Trauma Research Centre Questionnaire on Health Problems (OSTRC-H). MA injuries were recorded from physiotherapy reports. Cox proportional hazard regressions explored the association between prior injury and MA injury. Generalised linear mixed-effects models were used to model the association between OSTRC-H responses and a MA injury within 7-days. The predictive ability and accuracy of OSTRC-H responses were also assessed. **Results:** Prior injury was not significantly associated with a greater risk of MA injury during BMT. Self-reported physical complaints effecting 'participation' ("Full participation, but with injury/illness" odds ratio [95% confidence interval] = 2.23 [1.97, 2.52]; "Reduced participation due to injury/illness" = 3.19 [2.54, 4.00]), 'severity' ("To a mild extent" = 2.19 [1.91, 2.51]; "To a moderate extent" = 2.83 [2.38, 3.36]; "To a severe extent" = 4.50 [3.26, 6.21]), and 'location' (2.19 [1.96, 2.45]) were significantly associated with greater odds of MA injury within 7-days. Spine (4.39 [3.07, 6.30]), upper- (2.45 [1.76, 3.40]) and lower-extremity (2.73 [2.40, 3.11]) physical complaints were significantly associated with a MA injury to the corresponding general body region within 7-days. Using the presence of a physical complaint to indicate the occurrence of a MA injury within 7-days resulted in a high number of false positives and false negatives (area under the curve: 0.51–0.66). **Conclusions:** Independently, self-reported 12-month prior injury was not significantly associated with a greater risk of a MA injury during BMT. Daily self-reported physical complaints may however flag increased MA injury risk, which could help prevent more severe injuries. **Military Impact:** Considering most injuries sustained during BMT are overuse related, the early detection of physical complaints, via a modified OSTRC-H, may be particularly useful to facilitate secondary injury prevention strategies during Australian Army BMT.

Board 11: Hamstrings work demands during heavy load carriage are related to walking slope

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Purpose: Hip muscle weakness contributes to risk of lower limb and lumbar spine injury, which comprise 60 – 80% of all musculoskeletal overuse injuries in the military. Carrying heavy backpacks on slopes requires modified hip joint power generation and absorption relative to level, unloaded walking, which is achieved through muscle work. The purpose of this study was to quantify hamstring muscle work during sloped and loaded walking while using different backpack implementations. **Methods:** Body kinematics and ground reaction forces were collected in Cortex (Motion Analysis Corp, Rohnert Park, CA) from six (five male, one female) active-duty participants (height: 1.74 ± 0.08 m, mass: 78.5 ± 9.5 kg, age: 29 ± 7 y) while walking on −10° (Down), 0° (Level), and +10° (Up) slopes. Load conditions were completed in a randomised order with 10 min rest periods between and included participants wearing body armour and a helmet (~ 6.5 kg, NoPack) and two 40% body weight conditions where the remaining backpack mass was supported by shoulder straps only (Shoulder) or shoulder straps and a hip belt (HipBelt). From the experimental data, we developed sloped walking simulations using OpenSim 4.3 (simtk.org) of calibrated models with backpack attachments for each participant and backpack condition. Muscle states were solved with Computed Muscle Control. Musculotendon power from biceps femoris long head (BFLH) and semimembranosus (SEM) was integrated over right strides to obtain concentric and eccentric work. We compared muscle work using ANOVA ($\alpha = 0.05$) with main effects of backpack, slope, and the backpack-by-slope interaction. Post-hoc pairwise comparisons using Tukey's HSD were performed. **Results:** A main effect of slope was found in BFLH and SEM concentric work ($p < 0.001$ for both), which produced 2.5 and 7.1 J during Down and increased to 9.6 and 13.0 J during Up, respectively ($p < 0.005$ for all pairwise comparisons). A main effect of pack was found in BFLH concentric work ($p < 0.001$), which increased from 4.2 J in NoPack to 6.0 J in both HipBelt and Shoulder ($p < 0.001$ for both pairwise). The backpack-by-slope interaction was significant for BFLH eccentric work ($p = 0.036$). In all three backpack conditions, BFLH eccentric work during Up (NoPack: 7.6, HipBelt: 13.2, Shoulder: 14.8 J) was greater than during Down (NoPack: 3.4, HipBelt: 4.9, Shoulder: 5.3 J) and Level (NoPack: 2.5, HipBelt: 5.9, Shoulder: 5.6 J). While BFLH eccentric work increased with walking slope in HipBelt and Shoulder conditions, eccentric work was least during Level in the NoPack condition. In addition, BFLH eccentric work was greater during HipBelt and Shoulder, compared with NoPack while walking Up. A main effect of slope was also found in SEM eccentric work ($p < 0.001$). However, in contrast to BFLH results, SEM eccentric work was greatest during Down (10.6 J) and decreased progressively with increasing walking slope (Level: 9.4 J, Up: 6.5 J; $p < 0.005$ for all pairwise). **Conclusions:** These results should be interpreted considering the small sample size, which reduces generalisability of these findings. However, effect sizes (not reported) were large for all main and interaction effects. Our results demonstrate greater eccentric work from the BFLH compared to SEM, consistent with greater

prevalence of BFLH injury. These findings can inform training recommendations for heavy load carriage on varied terrains. **Military Impact:** Military service members may need to consider hamstring strength and flexibility, particularly in the BFLH, to mitigate injury risk during heavy load carriage on slopes.

Board 12: A wearable sensor system for in-flight measurement of neck loads in fast jet aircrew: key observations from typical air combat manoeuvres

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Purpose: Aircrew suffer neck pain at twice the rate of civilians. Operationally significant neck pain remains the biggest burden in days lost for fast jet aircrew. Aircrew are exposed to increased neck loads through a combination of high gravity loads, head position, and varied helmet weight and configuration. Exposures measured by flight time, ratings of perceived exertion, electromyography, and G-force (Gz) are unable to determine intervertebral load exposure. We report the first results of in-flight measures of spinal load using a validated inertial sensor system worn by aircrew in-flight. **Methods:** At ICSPP 2020 we reported the development of a sensor fusion algorithm capable of estimating cervical segment moments with 0.7 to 3% accuracy compared to 3-D motion capture methods. This model has since been integrated into a system of inertial sensors secured on the head and torso of aircrew, with a reference sensor mounted to the airframe. A second model makes adjustment for helmet mass and configuration properties. A third model reliably classifies each headcheck or posture. By integrating head position data, helmet mass properties, with Gz, estimations of intervertebral segment loads are derived and reported when the sensors are docked and downloaded. A summary of key findings related to neck loads in the upper (C1), mid (C4), and lower (C7) regions, during typical flight manoeuvres is reported here. **Results:** High variability of neck loading was evident between and within aircrew, with mean loads differing by up to 30% for the same flight manoeuvre. The Joint Helmet Mounted Cueing System (JHMCS helmet) resulted in higher moments at each segment by a factor of 1.25 per unit of Gz at C1, and by a factor of 1.08 per unit of Gz at C7. Technique differences were observed between the Left and Right Check6 (looking to the rear of the aircraft) motions. The mean instantaneous sum of moments expressed as a proportion of head mass differed across the spinal segments and with wide variation: mean ± SD, C1 = 11 ± 7%, C4 = 15 ± 18%, C7 = 17 ± 19%. High Gz flight with neck extension combined with rotation was associated with highest peak loads and highest cumulative loads. **Conclusions:** Peak and cumulative loads are dependent on flight profile, helmet properties, and headcheck technique. Neck loads experienced in flight vary within and between pilots. Monitoring neck load must be individualised to account for contextual variance. **Military Impact:** This study highlights individual variance of in-flight neck loads in fast jet aircrew. Neck load monitoring is now possible in-flight and should inform risk management and technique optimisation.

Board 13: Can the Y-Balance test be used as a predictor of injury occurrence during military training?

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Purpose: The intensive nature of military training can result in the occurrence of musculoskeletal injuries during training. The Y-Balance test (YBT) is a dynamic test which assesses strength, stability, balance, flexibility, and motor control. It has been used to predict injury risk in athletic populations but has not been widely used for the same purpose in the military. **Methods:** YBT composite scores normalised to limb length for the upper quarter and lower quarter from a total of 213 cadets (67 women, 146 men) were collected as part of a pre-entry fitness program. YBT reach asymmetry (a difference of 6 cm for the lower quarter posteromedial and posterolateral reach and 4 cm for the lower quarter anterior reach and all upper quarter reach distances) was calculated based on individual reach distances collected during the pre-entry assessment. Self-reported data on injuries obtained during military training were collected prior to officer cadet commissioning. Student's t-test and Welch's t-test were used to compare composite scores between cadets who reported obtaining a musculoskeletal injury during training compared with those who did not. The Chi-squared test was used to compare the presence of asymmetry in YBT reach. **Results:** Pre-entry composite scores for the right upper quarter ($p = 0.01$), left upper quarter ($p = 0.006$), right lower quarter ($p = 0.01$), and left lower quarter ($p = 0.004$) were significantly lower in cadets who sustained at least one musculoskeletal injury during training compared with those who were uninjured. Only the presence of asymmetry in the posteromedial reach for the lower quarter YBT was significantly different between cadets with and without an injury ($p = 0.03$). The presence of asymmetry in other YBT reaches for cadets with and without an injury were not significantly different. **Conclusions:** YBT composite scores may be used to predict injury risk prior to entering the military. However, YBT asymmetries cannot be used for the same purpose. Further analysis is required to determine cut-off scores or norms for identifying individuals with higher injury risk. **Military Impact:** The YBT can be used as a pre-entry screening tool to identify individuals at risk of injury as a focus for injury prevention interventions carried out during training.

Board 14: Implementation of Rehabilitation Exercise (PX) in the Singapore Army

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Purpose: Through performing functional movement screening (FMS) on Officer Cadets in a previous study, it was found that the main deficits were reduced lower limb flexibility and core stability, which commonly leads to back, knee, and ankle injuries. To address this, Singapore Armed Forces Physiotherapy Centre (SPC) designed a 20-min rehabilitation exercise (PX) program to reduce the risk of musculoskeletal injuries (MSKI). PX was first trialed with

subsequent Officer Cadets, and it was introduced to all Army units in the Singapore Army by the end of 2021 for a trial implementation. This implementation in the Singapore Army— as one of the strategies to reduce MSK attrition—involved many stakeholders, with the biggest challenge being the education of units. The aim was to share the experience of implementation of PX in the Singapore Army and to identify the concerns of implementation. **Method:** Implementation and program design: PX consists of exercises aimed to increase flexibility, mobility, and strengthening of the back and lower limbs muscles. Each PX program consists of 14 to 15 exercises and can be done individually or as a group. The conduct of PX is done daily, and preferably conducted in the morning to prepare for the day's physical activities. Training: multiple media were produced to aid in the conduct of PX, including a YouTube video, and a manual with visual and written instructions. Each unit sent their commanders for a two-hour train-the-trainer session. A total of 21 sessions were conducted. Army-wide trial implementation: an army-wide review of training programs was conducted, where PX was implemented. A one-year post-implementation survey was conducted in September 2022 for the unit commanders to assess the frequency of PX conduct, reasons if not conducting, and the effectiveness of the training provided. **Results:** Of the 27 returned surveys, 92.6% understood the benefits of PX. However, only 77.8% of the units were conducting PX twice a week or more, citing insufficient time. 40.7% of the respondents did not receive any training; despite this, 85.2% of them still felt confident and well-equipped to conduct PX, as 96.3% found the YouTube videos aided them sufficiently in the conduct of PX. **Conclusions:** Education and ease of conduct for the commanders were important factors in determining the success of implementation. The implementation team will consider the current feedback when doing the training program review to include PX as part of the daily curriculum. **Military Impact:** The implementation of PX is aimed at reducing the risk of injury soldiers, which will in turn ensure a strong fighting force for the Singapore Army.

Board 15: The effect of external load on approximated centre-of-mass vertical movement during treadmill marching

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Purpose: The vertical motion of the centre of mass during walking is thought to reduce metabolic cost due to pendulum-like mechanical energy exchange. However, it has also been hypothesised that reducing centre-of-mass movement reduces metabolic cost via foot and knee mechanics, among others. We have recently shown that lower limb coupling variability increases with heavier loads. The aim of this study was therefore to investigate centre-of-mass vertical movement across a range of military-relevant marching loads. **Methods:** Seventeen Australian Army soldiers (5 females, 12 males; height 178 ± 9 cm, body mass 81 ± 16 kg, age 25

± 5 y) completed three 12-min walking trials on an AMTI dual-belt instrumented treadmill. All trials were performed at 5.5 km·h-1 with three increasing absolute loads (0 kg [control], 23 kg [patrol order], 35 kg [marching order]). Twelve minutes of rest was provided between each trial. Centre of mass location was approximated using the midpoint of reflective markers attached to the anterior and posterior superior iliac spines of the pelvis and tracked using a Vicon motion capture system (120 Hz). Centre of mass vertical movement was measured using the standard deviation and average range (average maximum – average minimum) across 20 strides during the second minute of each trial. Linear mixed models were used to assess the effects of load on these variables ($\alpha = 0.05$). Paired-sample t-tests were performed where significant main effects were found. **Results:** There was a significant effect of load on standard deviation ($p = 0.011$), whereby the 35 kg condition (mean ± standard error; 20.7 ± 0.80 mm) was significantly more variable than the 0-kg (18.9 ± 0.77 mm, $p = 0.012$), and 23 kg (19.2 ± 0.75 mm, $p = 0.030$) conditions. There was a significant effect of load on average range ($p < 0.001$), whereby the 35 kg condition (64.7 ± 2.52 mm) had significantly more vertical movement than the 0 kg (56.3 ± 2.39 mm, $p < 0.001$) and 23 kg (57.6 ± 2.32 mm, $p = 0.003$) conditions. **Conclusions:** Marching with 35 kg of external load elicits a significant increase in centre-of-mass vertical movement compared with 0 kg and 23 kg of load. It is possible that the increased variability in centre-of-mass vertical movement is an attempt to reduce metabolic cost via mechanical energy exchange and this may be achieved through an increase in lower-limb coupling variability. **Military Impact:** Targeted lower-limb strength training may increase load carriage efficiency by improving mechanical energy exchange during marching.

Board 15: Assessing biomechanical and physiological responses to training in female warfighters using virtual avatars

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Purpose: While female soldiers remain a minority in the military, they experience a disproportionately high number of musculoskeletal injuries (MskIs). It is unclear whether the prevalence of MskIs in female soldiers is due to anatomical differences or differences in physical fitness. This study had two main goals: (1) determine whether a joint-based MEE model (JBM) produces results comparable to the literature, and; (2) compare the results for various exercises to investigate potential differences between men and women. **Methods:** Motion capture data was collected for participants (1 24y/o male, 1 42y/o female) as they performed level-ground, unloaded treadmill walking at 0.8 and 1.3 $m{\cdot}s^{-1}$ and level-ground, loaded treadmill walking at 1.3 $m{\cdot}s^{-1}$ with backpack loads of 9 and 18 kg. Physics-based simulations were performed using OpenSim, producing simulated joint kinematics and ground reaction forces (GRFs). An inverse dynamics algorithm was then used to calculate joint moments. The participants' MEE were estimated for each trial using Cruz and Yang's JBM as well as the Pandolf and Load

Carriage Decision Aid (LCDA) equations. **Results:** The LCDA equation produced lower MEE estimates than the other models in all cases. In the unloaded trials, the men's MEE estimates from the JBM (4.47 and 6.03 $W \cdot kg^{-1}$) closely matched those of the Pandolf equation (4.47 and 6.02 $W \cdot kg^{-1}$); however, the women's MEE estimates (5.68 and 8.70 $W \cdot kg^{-1}$) were considerably higher than the Pandolf estimates. For the loaded trials, the JBM estimates were consistently higher than the Pandolf estimates. The exercise intensity was greater for women than men, regardless of the model used. In the 9 kg loaded trials, the JBM, Pandolf equation, and LCDA estimated the relative exercise intensity factor for the men as 6.76, 5.55, and 3.83, respectively, and for the women as 10.18, 6.61, and 4.39, respectively. **Conclusions:** This study provides a preliminary sensitivity analysis of the JBM in common marching tasks. The results indicate the JBM can be used to guide development of varied Mission Planning Tools (MPT) protocols for different groups based on gender, fitness level, age, etc. Also, the JBM may be used to help understand how soldiers from different groups might respond to training regimens or combat missions. **Military Impact:** As the presence of women in the military continues to grow, it is becoming increasingly important to optimise MPT and mitigate injury risk. The JBM represents a promising new tool for evaluating MEE and injury risk using virtual avatars.

Board 17: Inclusion of rehabilitation as part of the management of the injured soldier

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Purpose: After an injury, the current process applied for the management of the injured soldier is managed by the medical functions and, if needed by the pathology, paramedical functions (physiotherapy, osteopath). However, with a prolonged cessation of professional and sporting activity, the soldier's job-specific performance is progressively degraded. These maladjustments lead to frailties, associated pathologies, and poor psychological outcomes. The inability to perform physically or psychologically can result in recurrence of injuries and slow the return to duty of the soldier. The objective of this new model of injury management, including performance rehabilitation, must allow for a quicker and sustainable return to function specific professional and sporting performance. **Methods:** Since December 2021, the Centre National des Sports De la Défense (National Defence Sports Centre – CNSD) trains all the second level specialists of the Physical and Military Sports Training domain in performance rehabilitation. At this point, a new model of injury management was established in the service de santé des armées (Joint Health Service – SSA). This new pathway of care includes—in consideration of the pathology—rehabilitation from initial paramedical or medical care towards a return to performance. During this process, the person in trained in rehabilitation corrects the different and various compensations and imbalances, and delivers a reconditioning protocol aimed at improving motor-function by adapting the physical preparation program, all whilst considering psychological processes. The rehabilitation professional is the last link in the chain elatioying return to duty and return to sport. **Results:** Thanks to better support in the circuit of care, rehabilitation drastically increases the mental and physical resources of the soldier during their sporting and professional return from injury. In this context, feedback indicates that repeated injuries are extremely rare. **Conclusions:** The success of performance rehabilitation has not been quantified but is the subject of several studies notably by the Canadian Armed Forces. Feedback and field debriefings allow us to support the argument that specialists in military and sports physical education are qualified in rehabilitation; this process can be established to improve the return of the soldier to 100% of their capabilities. **Military Impact:** At the end of the process, thanks to individualised tests oriented to their job, the soldier can resume their sporting and professional activity in an optimal manner. This procedure supports and provides confidence to the chain of command.

Board 19: Conception of a guided rehabilitation form after a lateral ankle sprain for the French Armed Forces with a Delphi method

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Purpose: Ankle sprains are the French armed forces most common musculoskeletal injury (MskI) with high recurrence rates recorded / reported. It is a major cause of unavailability, employment restrictions, and long-term sequelae-like pain, osteoarthrosis, or chronic instability. To cope with the military physical burden, they need to recover reliable proprioception, strong muscle stabilisation, endurance, and strength before returning to duty. To reduce the recurrence of injuries, experts of the International Ankle Consortium provide guided rehabilitation programs, however obstacles to offer this program to French soldiers include limited knowledge of military physical trainers, time-consuming explanations for physicians, and a lack of physiotherapists within units. The aim of this study was to build a relevant standardised rehabilitation program after an ankle sprain, guided by physical trainers. **Methods:** Few studies exist which investigate physical rehabilitation after ankle injuries, therefore a formalised consensus method called Delphi was used to compensate for the lack of scientific evidence within this area and / or to adapt this scientific evidence to a specific context. A literature review with proof grading was conducted to develop an initial rehabilitation program, which was assessed and scored from 1 (total disagreement) to 9 (total agreement) by a multidisciplinary expert committee. The committee included: rehabilitation doctors, sports physicians, physiotherapists, and physical training instructors. The final form is a more relevant and feasible version of the program with the practitioner's time constraints and the available equipment considered. Subject matter experts' opinion allows the program to be simplified and make its implementation easier. **Results:** The content of the final program is adapted to the specific constraints of a military environment compared to sport medicine guidelines: validated and simplified field tests to assess stability and self-confidence of the patient in their ankle and tools to rate their progress with a threshold allowing them to go back to weight-bearing sport. The style is also adapted to the users—military physical trainers with a simple single sheet in two parts: functional assessment with scoring and examples of rehabilitation exercises categorised by ability to

recover. Depending on assessment, the program rehabilitation has two steps of difficulties to specifically improve stabilising muscle strength, proprioception and flexibility, and preserve aerobic fitness with limited weight-bearing. **Conclusions:** This method is effective to create a scientific-based program but also to make this tool daily usable for military practitioners in field. Implementation of a Delphi method in a multidisciplinary expert panel is useful to adjust sport medicine guidelines developed for high level athlete to the military field and soldier. Its efficiency to prevent recurrence must be assessed. **Military Impact:** The expected impact is to facilitate the implementation of rehabilitation after MskI, directly in military units and guided by physical trainers with only physician supervision to improve sport recovery, return to duty, and reduce the recurrence of MskI in training and combat.

Board 20: Are parity status or injury history related to knee kinematics in a bodyweight overhead squat to assessment in military servicewomen?

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Purpose: Dynamic knee valgus is a strong predictor of injury and can be visually characterised as excessive medial knee displacement (MKD). A history of childbirth is associated with musculoskeletal injury in female members of the Canadian Armed Forces (CAF). While previous injury and pregnancy impact knee kinematics, it is unclear if a history of childbirth (parity) is associated with knee valgus. Using a bodyweight overhead squat to detect MKD, this study examined the relationship between asymmetrical frontal plane hip-knee-ankle angle (HKA) of female CAF members. **Methods:** 2D-video of 21 parous (have given birth) and 24 nulliparous (have not given birth) CAF members performing the overhead squat was used to assess HKA. Kinovea Software was used to manually determine HKA at the top and bottom of overhead squat repetitions, for both legs. One-way ANCOVA were used to compare: i) parous and nulliparous, and; ii) acute injury history. Two-way ANCOVA was used to assess parity status combined with acute injury history. Covariates included were years of service, long jump score, relative bench press strength, parity status (when injury is independent variable in one-way ANCOVA), and body fat percentage. Results are expressed as adjusted mean of HKA change (top to bottom of the overhead squat) and asymmetry (difference between left and right HKA). A p-value of < 0.05 was deemed significant and confidence intervals (CI) were calculated at 95%. **Results:** Overhead squat MKD asymmetry was not different between parous and nulliparous groups. When stratified by acute injury history body region, larger left to right HKA difference was observed for participants with a history of upper extremity acute injuries (10.46° vs 4.518°) ($p = 0.004$, $\eta p^2 = 0.209$). When parity status and acute injury history were combined, HKA asymmetry was greater for the parous / acute injury group (8.18° [CI: 5.270, 11.096]) compared with nulliparous / acute injury (4.530°, [1.693, 7.36]), parous / no acute injury (2.069°, [−2.446, 6.585), and nulliparous / no acute injury (6.040°, [1.952, 10.128]) ($p = 0.046$, $\eta p^2 = 0.106$). **Conclusions:** MKD asymmetry in the overhead squat was not related to parity status of female

CAF members. However, greater MKD asymmetry in the overhead squat was observed in i) parous / acute injury, and ii) upper extremity acute injury groups. These findings support the inclusion of the overhead squat when assessing movement of female military personnel with a history of acute injury. **Military Impact:** The overhead squat could be a helpful tool when developing physical training programs for female military personnel with previous acute injury, and parity status should be considered in conjunction with injury history.

Board 21: The validity of Loadsol® pressure insoles during treadmill load carriage across different speeds, external loads, and footwear

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Purpose: Military load carriage is commonly associated with increased musculoskeletal injury risk, hence there is a continuing need to identify and mitigate the factors that may contribute to these injuries. Recent technological advances allow the plantar force from each step to be measured in the field, and if the data provided by this technology is valid, it can be used to better understand the biomechanics of load carriage. This study examined the validity of Loadsol® force insoles during treadmill load carriage across different footwear types, speeds, and external loads. **Methods:** Eighteen Australian Army soldiers (one women) completed twenty-five 30-s intervals on an instrumented treadmill (1200 Hz) wearing Loadsol® force insoles (200 Hz). Trials were completed using both runners and boots, at a range of military relevant speeds (3.5 $km \cdot h^{-1}$, 4.5 $km \cdot h^{-1}$, and 5.5 $km \cdot h^{-1}$) and external loads (0 kg, 10 kg, 20 kg, and 30 kg). For the 0 kg runner condition, participants also ran at 10 $km \cdot h^{-1}$. Descriptive statistics and Cohen's d effect sizes were calculated to quantify the difference between peak vertical ground reaction forces and peak vertical plantar forces. **Results:** On average, across all walking steps included in the analysis ($n = 1439$) there was a 39.8 ± 114.9 N difference between ground reaction forces (mean = 1011.3 ± 165.2 N) and plantar forces (mean = 971.5 ± 179.5 N). Across all walking trials, insoles tended to underestimate ground reaction forces by 25.8 ± 118.0 N in boots ($d = 0.22$; 2.5 % difference) and by 53.4 ± 110.3 N in runners ($d = 0.48$; 5.6 % difference). Across all external loads, insoles underestimated vertical ground reaction forces during the 3.5 $km \cdot h^{-1}$ ($d = 0.73$; 11.7 % difference) and 4.5 $km \cdot h^{-1}$ trials ($d = 0.35$; 6.0 % difference), and overestimated forces during the 5.5 $km \cdot h^{-1}$ ($d = -0.20$; 3.3 % difference) and running trials ($d = -1.56$; 29.2 % difference). Across all walking trials, insoles were most valid during the 0 kg condition ($d = 0.21$) and least valid during the 10-kg condition ($d = 0.37$). **Conclusions:** Loadsol® force insoles provide an appropriate estimate of vertical ground reaction forces during walking treadmill load carriage, regardless of the speed and external load. However, the agreement between ground reaction forces and plantar forces is reduced during running compared with walking. **Military Impact:** Force insoles can be used to examine the biomechanics of load carriage in the field during walking.

Board 22: Simulation-informed machine learning model for predicting musculoskeletal kinetics of 'Shoot on the Move'

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Purpose: Characterisation of human musculoskeletal (MSK) kinetics during locomotion have informed exoskeleton design, leading to performance improvements in unimpaired users. Specifically, adaptive control through real-time estimation of kinetics has reduced the metabolic cost of walking. However, the ability to predict MSK kinetics during 'shoot on the move', a biomechanically distinct tactical walk implemented in operational environments, is unknown. This study aims to compare the kinetics of 'shoot on the move' with that of normal walking, and to evaluate a machine learning model for predicting kinetics from inertial measurement unit (IMU) data. **Methods:** Three males who are combat arms qualified performed 'shoot on the move' on an instrumented treadmill. Subject-specific inverse dynamics (ID) simulations (OpenSim) across two gait speeds (n = 18 strides at 1.1 $m \cdot s^{-1}$, and n = 18 strides between 1.3 $m \cdot s^{-1}$ and 1.8 $m \cdot s^{-1}$) were generated from motion capture and ground reaction force measures, and compared to reported kinetics of normal, level walking (Zoss et al., 2006, *Advanced Robotics*, 20.9, 967-988). A feed-forward neural network with ten input nodes (7 IMU joint angles, 3 IMU accelerations) was trained from ID outputs to predict lower-extremity joint torque profiles during 'shoot on the move'. Outputs were validated against remaining ID simulations using leave-one-out cross-validation. **Results:** The asymmetrical "shoot on the move" required less internal rotation power in the right (trailing) leg (5.17 ± 2.12 W) compared to the left leg (12.47 ± 6.99 W). No such asymmetries are apparent during normal walking. The right leg exhibited a prominent peak in external rotation (16.99 ± 9.02 W) compared with normal walking (<5 W). Toe-off of both legs occurred later in the gait cycle (72.16 ± 1.70%) compared with normal walking (~ 62%). Gait speed positively correlated with peak power in ankle flexion, hip flexion, hip extension, hip external rotation, and knee flexion. The neural network predicted joint torques from ID simulations with an R^2 between 0.612 (knee flexion) and 0.903 (ankle flexion), across all participants. Predictions for the subject with the most available training data demonstrated R^2 between 0.721 (hip rotation) and 0.935 (hip flexion). **Conclusions:** Lower-extremity kinetics of 'shoot on the move' are distinct from those of normal, level walking, as predicted by ID simulation. IMU measures may enable real-time estimation of these kinetics for calibrated exoskeleton control. **Military Impact:** Machine learning models for specialised movements such as 'shoot on the move', will likely be key components of control systems in exoskeletons designed for dismounted Warfighters.

Board 23: Comparison of strikes and front kick from an inverse dynamic's perspective and their protective benefit from a view of possible damage to the striking surface of the hand at the military personnel

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Purpose: Punches and kicks are commonly used in close combat, and their effectiveness can be analysed from an inverse dynamics perspective. Direct punch (DP) is a widespread strike but can result in hand injuries if not executed correctly or when hitting a solid target (helmet, protectors, etc.). To avoid this, palm strike (PS) and elbow strike (ES) can be used, as they do not require long-term strengthening of the striking surface of the hand. However, their effectiveness in terms of dynamic forces in comparison to DP and front kick (FK) is questionable. **Methods:** Eighteen Czech Army male soldiers (23.2 ± 3.4 y, 181.3 ± 6.8 cm, 82.9 ± 8 kg) performed three individual DP, PS, ES, and five individual FK. The dynamic forces were measured by the Force Plate. Peak force (N), impulse (N.s), and impact time during the contact phase (ms) were measured. Data were analysed using the Mann-Whitney test or paired sample t-test and Cohen's *d*. **Results:** The DP (2674 N) had a lower peak force than PS (4081 N), ES (4642 N), and FK (6418 N) by 53%, 74%, and 140%, respectively ($p = 0.0002$, $d = 1.42$; $p = 0.0001$, $d = 2.2$; $p = 0.0001$, $d = 3.27$, respectively). The impulse of DP (17.51 $N \cdot s^{-1}$) was not different than ES (17.58 $N \cdot s^{-1}$) ($p = 0.837$, $d = 0.02$) but higher by 18% than PS (14.86 $N \cdot s^{-1}$) ($p = 0.04$, $d = 0.72$) and lower by 842% than FK (164.9 N.s) ($p = 0.0001$, $d = 7.55$). Concerning the impact time, DP (17.38 ms) was longer by 48% than ES (11.77 ms) ($p = 0.0006$, $d = 0.77$) and by 114% than PS (8.12 ms) ($p = 0.0001$, $d = 2.14$) but shorter by 656% than FK (131.3 ms) ($p = 0.0001$, $d = 7.43$). The FK had higher peak force, impulse, and impact time than PS by 57%, 1010%, and 1517%, respectively, and higher than ES by 38%, 838%, and 1016%, respectively. **Conclusions:** PS and ES are approaching FK's peak force. PS, with a higher peak force and shorter duration, can cause more tissue damage upon impact than DP. **Military Impact:** FK has higher dynamic forces than punches, but PS and ES have higher dynamic forces than DP. Replacing DP with PS may be appropriate because the striking surface is naturally hardened, reducing the risk of injury when hitting a solid target.

Posters 2: Health and Wellbeing

Wednesday 13th September, 11:45 to 13:15

Board 24: Self-reported gastrointestinal symptoms and diarrhoea in Special Operations Forces personnel deployed to Afghanistan

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Purpose: Diarrhoea is a common non-battle injury that occurs in >50% of military personnel during some deployments and can negatively impact combat effectiveness. Previous studies have characterised the prevalence and impact of diarrhoea on health and readiness of conventional military units. However, few have done so in Special Operations Forces (SOF) who operate in small teams wherein each case of diarrhoea disproportionately impacts unit readiness. This retrospective observational study aimed to describe the prevalence of diarrhoea in SOF personnel during deployment and examine the relationship between self-reported gastrointestinal (GI) symptoms and occupational performance. **Methods:** Forty-six U.S. Army SOF personnel (mean ± SD, age 30 ± 3 y) completed a 14-item survey that queried GI symptoms, relevant exposures, and perceived consequences of GI symptoms during a six-month deployment to Afghanistan in 2018. Participants were primarily enlisted (87%) with 20 ± 14 cumulative months spent in a combat zone during military careers. The deployment consisted of time spent at both forward operating bases and austere outposts. **Results:** Of the Operators surveyed, 57% experienced ≥ 1 GI symptom during the deployment. Of those, 40% experienced nausea or vomiting, 53% moderate to severe abdominal pain, and 100% diarrhoea defined as 3 or more watery stools within 24 h. In those who experienced diarrhoea, onset occurred 4.3 ± 4.8 d after arrival into Afghanistan, the mean number of diarrheal episodes was 3.9 ± 2.8, and 80% experienced episodes lasting 2 to 6 days. These Operators also reported losing 1.5 ± 1.8 total duty days and reductions in physical or mental performance for 5.6 ± 6.1 days due to diarrhoea. Most (67%) participants that had diarrhoea never sought medical care. Rather, Operators frequently self-treated with Imodium / Loperamide (80%) and / or antibiotics (27%). Perceived causes of diarrhoea included eating meals ready to eat or food from the dining facility (60%) and / or eating from the local economy (47%), drinking uncertified water (27%), contact with an infected person (27%), and medication use (7%). Number of diarrheal episodes was strongly correlated with the number of days Operators perceived diminished physical or cognitive performance ($r = 0.743$, $p = 0.001$). **Conclusions:** In this cohort of Special Operators, diarrhoea was highly prevalent and associated with lost duty time and perceived decrements in physical and / or cognitive performance. **Military Impact:** As SOF operate in small teams, the impact of each case of diarrhoea may be proportionally greater than in conventional forces. Findings highlight the need for continued development and implementation of effective countermeasures.

Board 25: Heart rate variability profile of a specialist police selection assessor

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Purpose: Specialist police units such as Australian Police Tactical Groups (PTGs) are tasked with numerous duties, many potentially hazardous or fatiguing. One such duty is as a selection course (SC) assessor. Given the high physical intensity of SCs and imposition of sleep deprivation, health and performance monitoring may benefit SC staff and units. Heart Rate Variability (HRV) is one holistic measure obtainable from wearable technology. HRV effectively measures holistic stress response and can be practically integrated in tactical settings where other stress biosignals may not be feasibly acquired. However, while research has investigated candidate stress responses in challenging SCs, HRV measurements of SC staff have not been reported. Therefore, this case study aimed to profile HRV of a PTG SC assessor. Specifically, nonlinear SD1 (Poincare plot x-axis), SD2 (Poincare plot y-axis), and SD2:SD1 (geometric HRV ratio) were obtained, as these indices are robust to signal noise that may occur in austere conditions. **Methods:** The SC was a 32-h continuous battery of physical, occupational, and teamwork / leadership assessment tasks. The study volunteer wore a supplied EQ02+ LifeMonitor (Equivital™, Cambridge, UK) device, collecting a 2-lead ECG over 25 h. HRV data were reported as the summary of 298 consecutive short-term (5 min) measurements, illustrating changes with maximal resolution while maintaining measurement fidelity. HRV fluctuations were aligned with key SC events to profile HRV response in a novel population and setting. **Results:** The PTG assessor's HRV values demonstrated depressed dynamic adaptive response during on-duty hours. Specifically, while the assessor was responsible for coordinating safety and evaluating candidates during a land navigation exercise, HRV was limited (SD1 = 16.68 ms, SD2 = 124.7 ms). Some recovery was noted during a rest period (SD1 = 30.36 ms, SD2 = 130.2 ms). However, recovery was possibly incomplete; values rapidly returned to depressed levels once the assessor resumed working (SD1 = 28.5 ms, SD2 = 157.7 ms). **Conclusions:** This research agrees with previous investigations into extended specialist police on duty hours. Insufficient recovery may be marked by limited HRV increases despite rest or stress resolution. While limited, this research demonstrates that PTG staff are subject to high psychophysiological demands during PTG selection and establishes an initial objective characterisation of that demand. **Military Impact:** Personnel conducting SCs are subject to high psychophysiological demands. Unit leadership may consider the impact of SCs on assessment staff when developing a training and reinforcement cycle. Integration of an objective holistic stress measurement may also be advised.

Board 26: eHealth platform with integrated wearable biosensor facilitates scaling of targeted military fitness intervention

Alexander Nicholls [1], Joanne L Fallowfield [2], Jon Lord [1], Ben Fisher [3], Craig Watson [1], Anneliese Shaw [2], Ken Ayrey [1]

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Purpose: Musculoskeletal injuries related to body composition and training load represent significant health challenges for modern militaries. The resulting ill-health burden detrimentally impacts human performance, combat readiness, and operational effectiveness. Improving health behaviours can improve outcomes but changing health behaviour is often challenging and requires an innovative approach. A health and fitness Service Improvement Programme (SIP) was undertaken that aimed to facilitate scaling of the Defence Occupational Fitness (Dofit) health behaviour change programme by adapting a minimum viable product (MVP) eHealth platform (Smartabase) and conduct a process, outcome, and user-experience evaluation of the solution. **Methods:** Thirty soldiers participated in the 12-week SIP (median [IQR], age 26 [21, 34] y; mean ± SD, height 1.72 ± 0.10 m, body mass 90.0 ± 21.1 kg, waist circumference (WC) 97.4 ± 14.1 cm, and BMI 30.1 ± 5.1 $kg{\cdot}m^{-2}$). The process, outcome, and user experience evaluation considered: SIP development and implementation; Dofit compliance, adherence, and scalability; Dofit effectiveness from week-12 soldier outcomes (height, weight, WC, fitness [Soldier Conditioning Review score]), and; MVP user experience. Outcome data were checked for normality (Kolmogorov-Smirnov) and (week-1 *vs* week-12) differences assessed (paired t-tests). App use (chi-squared test), User Acceptability Questionnaire responses (Kruskal-Wallis H-test) and focus group data (main themes) were analysed. **Results:** Week-12 soldier outcomes were: + 4% physical fitness; −3% WC; and −2% body mass. One practitioner, using the e-health MVP, supported twice the number of soldiers (*i.e.*, 30 *vs* 15) and achieved the same outcomes as standard Dofit delivery. All soldier participants: successfully downloaded/registered and used the app >1 occasion during the programme; felt confident to share data (*i.e.*, security/privacy); shared discretionary (food diary/physical activity) and non-discretionary (anthropometry/fitness test) data with the practitioner via the app; and integrated the app with wearable devices. The MVP eHealth platform user experience was considered 'disappointing' by participants due to limited functionality, reliability, and intuitiveness. User experience combined with limited app-based practitioner feedback reduced participant data-sharing. Despite this, soldiers perceived the MVP eHealth platform promoted self-ownership, supported Dofit adherence, and resulted in positive health and fitness outcomes. **Conclusions:** Despite acknowledged functionality and user experience limitations, the MVP eHealth platform facilitated a two-fold scaling of standard Dofit service delivery whilst maintaining service quality. **Military Impact:** Successful military health and fitness interventions must promote self-responsibility and be supported by the environment and Chain of Command. eHealth solutions integrated with wearable biosensors could facilitate scaling of future health and fitness interventions in the military setting.

Board 27: The challenge of excess body fat in military personnel: prevalence and comparison between men and women

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**Contributed equally as senior authors*

Purpose: Excessive body fat poses a significant challenge to military law enforcement activity. It can have a negative impact on physical fitness, operational effectiveness, and soldier safety in combat situations. Furthermore, obesity is associated with an increased risk of chronic diseases and other health conditions, which can significantly impair the military's ability to fulfil its duties. However, there are no studies that have evaluated the prevalence of excess body fat among operational military personnel in São Paulo, and no gender-specific analyses have been conducted to compare the prevalence of excess body fat between men and women in this population. This study evaluated the prevalence of excess body fat in militaries in the State of São Paulo and compared men and women. **Methods:** 1293 militaries, including 168 women and 1125 men with a mean age of 35.4 ± 8.1 y, participated in this cross-sectional study. Participants underwent bioelectrical impedance analysis using the InBody 370 model to determine body fat mass. Body fat percentage (BFP) was classified as follows: a) normal (12-20% for men and 20-30% for women), and; b) above recommended levels (>20% for men and >30% for women). The data were analysed using GraphPad Prism (v.9) to determine the means and 95% confidence intervals (95% CI) and to compare genders with an unpaired t-test. Additionally, the chi-square test was used to examine the association between the gender variable and excess fat. **Results:** Women had a significantly higher a 39.1% mean higher BFP (33.3 ± 6.9%, 95% CI: 32.3, 34.4%) compared with men (23.9 ± 6.8%, 95% CI: 23.5, 24.3%) (p < 0.001) Despite this difference, there was no significant association between gender and the prevalence of excess fat in the groups. Among women, 22.1% had a normal body fat level, while 77.9% exceeded the recommended range. In the male group, 27.5% had a normal body fat level, while 72.5% exceeded the recommended range. **Conclusions:** The results indicated that women have a higher percentage of body fat. However, the prevalence of excess body fat is high in both groups and is not associated with gender. **Military Impact:** These findings highlight the importance of intervention strategies to prevent and treat excess body fat in military personnel, who may have their physical and tactical performance compromised, potentially impacting the operational activity of police and defence of society.

Board 28: The AVU-IGF: ensuring medical and operational readiness by means of a regular and comprehensive health assessment

Alexander Sievert [1], Ulrich Rohde [1], David Willems [1], Azad Ghasimi [1], Manuela Andrea Hoffmann [1]

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Purpose: Adequate medical readiness is a prerequisite for individual and force-wide operational readiness. The military medical examination “General Fitness for Service Examination for Individual Basic Skills” (AVU-IGF) was introduced to reduce and streamline the exuberant number of mandatory military medical assessments by eliminating redundancies, introducing a preventive aspect into the process, and to provide leaders with medical insights pertaining to the medical and operational readiness of their personnel. **Methods:** AVU-IGF is an obligatory, tri-annual medical examination determining the individual medical aptitude for participation in obligatory annual tests of individual basic skills (“IGF” = proficiency with the individual standard firearm, NBC- and medical training) and physical performance (“KLF” = 6 km ruck-march carrying 15 kg, Basic-Fitness-Test (BFT), swimming). Unit physicians assess health in all soldiers from 22 years and older, using a standardised protocol including detailed anamnesis, whole-body examination (including pulse and blood-pressure), lab-parameters from blood / urine, resting / exercise (if necessary) ECG, spirometry, vision test, and audiometry. Based on the results, individuals are graded “suitable”, “partly-suitable”, “temporarily-unsuitable”, and “permanently-unsuitable” for IFG/KLF participation. Assessments are stored digitally and will prospectively feed into a centralised health information management system. **Results:** A first look at aggregated AVU-IGF data revealed age and career path related effects on medical aptitude for overall IGF/KLF participation and for single tests. Further analysis provided statistical evidence for a significant impact of obesity and arterial hypertension on the individual IGF/KLF performance in Bundeswehr personnel. **Conclusions:** Cross-sectional AVU-IGF analyses underline that the unique combination of regular, comprehensive medical examinations with standardised processes and digitised data-collection provides evidence-based, valuable data to inform individuals and leaders. Hitherto unquantifiable threats to medical and operational readiness were identified, including subgroups where operational readiness may be compromised and / or action is most urgently needed. Given time, results can be complemented with force-wide longitudinal analyses or “soldier-lifecycles” on the individual level. The AVU-IGF database will serve as growing information source, enabling more specific approaches to individual or leader-based preventive or restorative measures. It will also feed into an evidence-based instrument to monitor individual and force wide medical readiness or assess the success of leadership health interventions. **Military Impact:** The regular and comprehensive health assessment of AVU-IGF enables early detection and continuous monitoring of individual and force-wide health risks and outcomes. Data can feed into preventive measures as well as into information systems for decision makers.

Board 29: Metabolic and inflammatory features of physically active and low-active military police officers

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Purpose: Obesity is a complex condition that has been associated with an increased risk of developing chronic diseases, including cardiovascular disease, type 2 diabetes, and cancer. It is also related to the establishment of a state of chronic inflammation, which can lead to metabolic dysfunction and contribute to the development of these diseases. However, regular physical activity has been widely recognised as an important factor in the prevention and control of obesity and its metabolic and inflammatory complications. The study aimed to compare the anthropometric, metabolic, and inflammatory parameters of physically active Military Police Officers (MPOs) with those who are low physically active. **Methods:** Fifty-six male MPOs participated and were classified by the International Physical Activity Questionnaire (IPAQ) as low activity ($n = 25$) and physically active ($n = 31$). The following parameters were measured: plasma cytokine, C-reactive protein (CRP), glucose triglyceride (TAG), and high-density lipoprotein cholesterol (HDL-C) levels; plasma glutamic oxalacetate transaminase (GOT), glutamic-pyruvate transaminase (GPT), and gamma-glutamyl transferase (GGT) activities; systolic (SBP), diastolic (DBP) and mean (BPM) blood pressure, and; perceived stress scale (PSS). The data were analysed using the GraphPad Prism to determine the means. The comparison between groups was performed using an unpaired t-test. Pearson correlation test was used for correlation analysis. **Results:** A higher metabolic equivalent (3.5-fold, $p < 0.001$) and lower waist circumference (8.3%, $p < 0.05$)], body mass (9.4%, $p < 0.05$), waist hip ratio (3.4%, $p < 0.05$), absolute fat mass (29.1%, $p < 0.05$), fat mass index (27.4%, $p < 0.05$), and visceral adipose tissue (27.4%, $p < 0.05$) were observed in the physically active group compared with the low activity group. The physically active group had lower plasma TAG (27.7%, $p < 0.05$), IL-8 (40.3%, $p < 0.05$), GGT (58.2%, $p < 0.05$), and perceived stress (37.8%, $p < 0.05$) levels than the low activity group. A negative correlation between PSS and SBP, DBP, and BPM was detected for the physically active group ($p < 0.05$), but not in the low activity group. The physically active group's work time values were not correlated with the notable metabolic markers SBP, DBP, BPM, GLU, and TAG ($p > 0.05$) but were in the low activity group ($p < 0.05$). **Conclusions:** These findings highlight the fundamental protective role of physical activity in controlling body composition, subclinical inflammation, and cardiovascular risk in MPOs. **Military Impact:** Promoting healthy habits among MPOs can improve their overall health, reduce the risk of diseases and inflammation, and enhance the police force's ability to fulfil its mission.

Board 30: High versus low self-perceived occupational demand profiles among employees of the Dutch Gendarmerie Corps

Pablo Stegerhoek [1], Jesse van der Zande[2], Caroline Bolling [1], Herman Ijzerman [2], Evert Verhagen [1], Paul Kuijer [1]

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Purpose: High occupational demands are associated with adverse soldiers' health outcomes, reduced performance, and challenges in maintaining operative capability. Occupational demands are high in military police populations and as far as we know, profile characteristics in this population have not been identified yet based on occupational demands. The study aimed to identify profiles based on self-perceived occupational demands among the Dutch Gendarmerie Corps, the Royal Netherlands Marechaussee. **Methods:** A digital survey was performed among all 7,658 Royal Netherlands Marechaussee employees in 2021. Latent profile analysis was used to identify profiles based on the following nine indicators of occupational demands: physical workload, mental workload, physical fatigue, mental fatigue, experience, boredom, task clarity, autonomy, and work support. These nine indicators were selected based on previously performed focus groups and interviews among 92 Royal Netherlands Marechaussee employees. Analysis of variance was used to determine if the profiles differed significantly across all indicators. Logistic regression was used to investigate which of the nine indicators were predictors of profile membership. **Results:** 1,763 Royal Netherlands Marechaussee employees completed the survey (response rate 23%). Due to missing data on 225 employees, the surveys of 1,538 employees were included in the analysis. A low and a high occupational demands profile were distinct across all indicators. For the low occupational demands profile, the five indicators were experience (OR [95% CI] = 1.02 [1.00 – 1.04]), mental workload (1.41 [CI 1.25 – 1.59]), task clarity (1.49 [1.32 – 1.69]), autonomy (1.18 [1.06 – 1.31]), and work support (2.63 [2.26 – 3.09]). For the high occupational demands profile, the three indicators were boredom (0.14 [0.10 – 0.20]), physical (0.42 [0.32 – 0.54]), and mental fatigue (0.18 [0.13 – 0.25]). Only one indicator, the physical workload indicator (0.96 [0.88 – 1.05]), was not associated with either of these two profiles. **Conclusions:** A high versus a low self-perceived occupational demands profile could be identified among Royal Netherlands Marechaussee employees. Remarkably, physical workload did not predict either profile. **Military Impact:** The eight occupational demands indicators can be used to improve the quality of work of military police in order to prevent adverse health outcomes and maintain operative capability.

Posters 2: Epidemiology

Wednesday 13th September, 11:45 to 13:15

Board 31: Challenges in advanced foodborne disease outbreak surveillance systems: identifying and handling algorithmic bias using the national outbreak reporting system, 2009-2019

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Purpose: In deployed and non-deployed military settings, acute gastrointestinal (GI) and diarrhoeal diseases have been a consistent cause of significant morbidity and mortality. A common, costly and preventable cause of acute GI and diarrhoeal disease is foodborne illness. While centralised testing and reporting of foodborne disease outbreaks (FBDO) across the US Department of Defense is lacking, publicly available FBDO surveillance systems offer alternative ways to examine the burden of foodborne illness on military readiness and health system resources, and the potential for non-random missingness and consequent algorithmic bias. **Methods:** Using FBDO records from Centers for Disease Control and Prevention's National Outbreak Reporting System from 2009-2019, we identified patterns of missingness (POM) and quantified the resulting algorithmic bias to inform the development of robust military public health surveillance systems. Among primary sources of algorithmic bias related to FBDO data collection and reporting (spatial and temporal validation, reporting standards and procedures to define categories), we examined the proportion of missing data in select FBDO characteristics (geographic locations; illness, exposure and global duration; implicated food product). We determined POM (completely at random or structural) and quantified their effects on FBDO caseload using pairwise t-tests with Bonferroni correction and logistic regression models. **Results:** Among 9407 records, 9019 (96%) and 388 (4%) were associated with single and multistate outbreaks, respectively. On average, the caseload of multistate FBDOs were ~ 3.3 times more than single state (53.1 cases [95% CI: 52.4, 53.8] *vs* 16.2 cases [16.1, 16.2], respectively, $p < 0.001$). Of records assessed, 25% (n = 2370) were missing a combination of illness and exposure start and end dates, restricting estimation of illness, exposure and global duration to 9116 (97%), 7119 (76%), and 7037 (75%) FBDOs, respectively. For 7111 (76%) FBDOs, implicated food products were categorised as missing (n = 5456, 58%), undetermined (n = 353, 4%), unclassifiable (n = 51, < 1%), other (n =50, < 1%) or invalid (n = 5, < 1%). **Conclusions:** The effect of structural missingness in essential FBDO characteristics demonstrates the for potential algorithmic bias that could jeopardise the reliability of FBDO surveillance. Improvements in data infrastructure are critical to minimise structural missingness, prevent potential algorithmic biases, and strengthen system predictive capacities and food safety policies. **Military Impact:** Data availability does not translate to usability, where underestimation of any security threat due to algorithmic bias could lead to inefficient resource utilisation, development of ill-informed emergency response and preparedness plans, and implementation of ineffective and inadequate detection, prevention, and monitoring strategies.

Board 32: U.S. Defense Safety Oversight Council (DSOC) Military Injuries Working Group (MIWG): a collaboration to reduce military injuries

Michelle Canham-Chervak [1], Bruce H Jones [1], Veronique D Hauschild [1], Anna Schuh-Renner [1], Christopher Phyon [1], KaSaundra Oden [1], John Scott [2], Karen Nelson [2]

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Purpose: This presentation describes the successes of a collaborative workgroup of U.S. military agencies involved in various aspects of military injury prevention. The Military Injuries Working Group (MIWG) was established because injuries remain a leading barrier to U.S. military medical readiness, with over 4.7 million medical encounters and an estimated 25 million days of limited duty related to injury among U.S. Service members annually. **Methods:** The MIWG was chartered in 2019 under the Defense Safety Oversight Council (DSOC), with members from 15 military organisations representing safety, public health, and research. Initial MIWG objectives assigned by the DSOC included establishing a definition of injury and developing standardised reporting methods for analyses of military Service members' medical records. For these objectives, the MIWG selected the Army Public Health Center's Taxonomy of Injuries and applied it with analyses of injury-related medical encounters for all U.S. military Services (Army, Navy, Marine Corps, Air Force). Subsequent MIWG objectives resulted in a quick reference tool (QRT) to improve use of injury external cause codes in medical records, and a comparison of the medical injury data to U.S. military safety investigation data. **Results:** Across all U.S. Services, injury was the leading reason for seeking medical care (42.0 – 49.7% of all medical encounters). Most injuries resulted from mechanical energy transfers (> 95%), affected the musculoskeletal system (> 82%), and were due to cumulative microtrauma or "overuse" (> 72%). The top three mechanisms of unintentional injury, representing nearly 50% of all cause-coded injury medical encounters across all Services, were overexertion, falls, and struck by/against. Less than 10% of injuries in the medical records had documented causes, while nearly 100% of safety data contained cause information. However, safety data captured only a small proportion of initial injuries reported in medical records (on average 1%). **Conclusions:** The MIWG's analyses revealed similar distributions of injury categories and leading causes across the U.S. Services. With improved cause coding with QRT use, medical records will provide actionable information into underlying causes of injury to supplement safety data. Investigations of medical and safety data and comparisons across Services support the development of policy, programs, and initiatives to reduce military injuries. **Military Impact:** Injuries are a complex, multi-faceted military health issue. As such, data on injurious sources of energy transfer and causes of injury furthers understanding that enables prevention planning. Partnerships, such as those formed under the DSOC MIWG, are essential to advancing military injury prevention.

Board 33: Burden and risk factors for plantar fasciopathy in the military population from 2006 to 2015: a retrospective cohort study

Jennifer Xu [1], Susan A Saliba [1], John J Fraser [2],

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Purpose: Plantar fasciopathy (PF) is characterised by foot pain exacerbated during loading. This condition limits military personnel from fulfilling their duties, especially those in occupations that require marching while carrying a load, resulting in diminished operational readiness and ability to complete mission objectives. Understanding the burden of PF in the military is important so that appropriate resources can be allocated to prevent and treat this condition. The purpose of this study was to examine the epidemiology and associated factors of PF in the US military. **Methods:** The Defense Medical Epidemiology Database was used to identify all episodes of PF diagnosed in military personnel from 2006-2015 using ICD-9-CM codes (728.71, plantar fibromatosis and 726.73, calcaneal spur). Prevalence ratio (PR) estimates were used to compare the factors of sex (within occupation) and occupation, with male service members, enlisted infantry, and ground/naval gunfire officers used as reference categories. A negative binomial regression (adjusted for zero inflation) was used to evaluate the factors of sex, age, rank, and service branch on PF outcomes. **Results:** Multiyear prevalence of PF was 13.80 / 1000 in officers (male: 12.94 / 1000, female: 18.39 / 1000) and 12.66 / 1000 in enlisted (male: 11.55 / 1000, female: 19.32 / 1000), with only small magnitude significant increases in burden in the latter eight years of the study epoch (PR range: 1.10 – 1.20). Female officers (PR: 1.42) and enlisted (PR: 1.67) had significantly greater risk of PF compared with their male counterparts. Compared with the reference groups, all but two officer specialties (aviation and logistics) and one enlisted specialty (special operations) had significantly greater risk of PF (PR range, officers: 1.29 – 1.58; enlisted: 1.21 – 1.64). Junior officers (PR: 0.66) and senior officers (PR: 0.69) had significantly lower risk compared with junior enlisted and service in the Army had the greatest risk of PF. Female sex (PR: 2.05) and ages ≥ 30 y (PR range: 3.02 – 5.04) were salient factors when rank, branch, and year were controlled. **Conclusions:** Multiple factors were associated with PF in the military population, including sex, age, rank, military occupation, and service branch. Future research investigating factors that may contribute to PF such as sex-related differences in biomechanics, post-partum effects on foot morphology, occupational demands, and care-seeking behaviours across military occupations and branches is warranted. **Military Impact:** These findings highlight the need to identify interventions for PF and populations who can most benefit from the interventions, and may help military leaders consider how to plan for clinicians and supplies needed to address PF.

Posters 2: Environmental Stressors, Exposure, and Injuries

Wednesday 13th September, 11:45 to 13:15

Board 34: Physiological markers of heat stroke during loaded ruck marches

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Purpose: Exertional Heat Stroke (EHS) remains a stubborn challenge for military communities around the world. Severe EHS can lead to organ damage and even death without rapid treatment. EHS often occurs during events with high metabolic demands coupled with a high level of individual motivation. Physiological monitoring (PM) may provide early warning that an individual is at risk of EHS. In order to optimise PM, we must understand how the physiological response of individuals who suffer an EHS differs from those who did not. The purpose of this work was to compare the physiological profiles of individuals who experienced EHS with those of others completing the same training event, who did not. **Methods:** Heart rate (HR), chest skin temperature (T_{sk}), and estimated core temperature (T_{ect}) were collected using a chest-mounted physiological monitor (HIPS, ODIC, Littleton MA) on six individuals who experienced an EHS (age = 22.7 ± 3.6 y, height = 1.8 ± 0.1 m, body mass = 87.6 ± 10.6 kg, Tr = 41.5 ± 0.5°C at collapse.) during one of 3 loaded ruck march events (Ranger 12 Miler, Marine Infantry Officer Course 10 Miler, or Marine Crucible). Similar data were collected on three controls for each of the EHS cases, matched for age, height, body mass, and two-mile run time (n = 18, age = 21.5 ± 2.5 y, height = 1.8 ± 0.1 m, body mass = 86.9 ± 10.7 kg). Each ruck was divided into four equidistant quarters. Mean HR, T_{sk}, and T_{ect} were computed for each quarter. The ruck march physiology profiles were compared using a 2-way ANOVA. **Results:** T_{ect} rose over time ($p < 0.001$) with higher T_{ect} in EHS than the controls (37.9 ± 0.3 to 38.6 ± 0.3 °C vs 38.1 ± 0.4 to 39.2 ± 0.9 °C respectively, $p < 0.001$). HR was higher for EHS ($p < 0.001$) and showed a different pattern over time ($p < 0.03$). In controls, HR remained constant (142 ± 22 b·min-1) but increased progressively in EHS (154 ± 25 to 164 ± 25 b·min-1). T_{sk} in EHS was higher ($p < 0.001$) and showed an inverse pattern over time ($p = 0.13$) compared with the controls (EHS T_{sk} rose from 37.1 ± 1.5 to 38.2 ± 2.1°C, where for the controls T_{sk} decreased from 36.0 ± 0.8 to 35.4 ± 1.1°C; $p < 0.05$ for both). **Conclusions:** It can be difficult to distinguish EHS cases from controls with a higher HR and core temperature. The differential response of HR and T_{sk} over time may provide a method of identifying individuals who are at risk for EHS. **Military Impact:** By identifying individuals at risk of EHS, training cadre can make informed decisions and take appropriate interventions to prevent a potentially catastrophic illness. **Disclaimer:** Author views not representative of the United States Army or Department of Defense.

Board 35: Influence of hand temperature on core temperature afterdrop following cold-water immersion in operational settings

Douglas M Jones[1], Rebecca Weller[1], Rebecca McClintock[1], Timothy Dunn[1]

[1]Naval Health Research Center, USA

Purpose: Warfighters who experience accidental cold-water immersion (CWI) are susceptible to rapid body heat loss resulting in significant cold stress and hypothermia. Once removed from cold water, core temperature (T_c) may continue to fall due to "afterdrop," wherein cooler blood in extremities recirculates to the core region of the body and causes a further reduction in T_c. It is hypothesised that those with lower hand temperatures (T_{hand}), reflective of lower extremity temperatures and thus cooler blood, may experience a greater magnitude of afterdrop. The aim was to measure the afterdrop in a large military population and to evaluate the influence of T_{hand} on afterdrop. Methods: Ninety military personnel (mean ± SD, age: 27 ± 6 y, height: 176 ± 8 cm, weight: 81.5 ± 11.6 kg) performed a 10-min CWI (1.3°C) in an outdoor environment (−4°C). T_c and T_{hand} were measured continuously before, during, and after CWI. Following CWI, participants donned dry clothing and entered a sleeping system (*i.e.*, sleeping bag and ground pad) to initiate rewarming. Afterdrop was calculated as the difference in T_c from the time of water egress to the minimum T_c following water egress. Lowest T_{hand}, which always occurred during CWI, was used to evaluate the relationship between extremity temperature and afterdrop using Pearson correlations. Afterdrop data were also divided into three groups: small (1°C; n = 29), medium (1 – 2°C; n = 49), large (> 2°C; n = 12), and T_{hand} was compared between groups using a one-way ANOVA. Statistical significance was set at $p < 0.05$. **Results:** Mean ± SD T_c afterdrop for the small, medium, and large groups was 0.6 ± 0.2°C, 1.4 ± 0.3°C, and 2.4 ± 0.2°C, respectively. Lowest T_{hand} was not different between each group (small: 8.6 ± 0.3°C, medium: 7.7 ± 2.5°C, large: 9.0 ± 3.5°C; p = 0.172), and no relationship was observed between afterdrop and lowest T_{hand} (r = 0.013; p = 0.905). **Conclusions:** Findings suggest that T_c afterdrop is highly variable within a large military population performing a brief CWI in an outdoor setting. Contrary to our hypothesis, colder T_{hand} during CWI does not accurately predict the magnitude of T_c afterdrop. **Military Impact:** Warfighters accidentally immersed in cold water should expect further reductions in T_c following CWI, which could promote greater vulnerabilities and complications associated with hypothermia. Currently, it is not recommended that T_{hand} be used to estimate afterdrop magnitude.

Board 36: Evaluation of thermal and pain sensations to predict frostbite risk during localised cold stress and recovery

Rebecca Weller [1], Rebecca McClintock [1], Tony Duong [1], Joseph Cuellar [1], Alice LaGoy [1], Pinata Sessoms [1], Matthew Peterson [1], Timothy Dunn [1], Douglas M Jones [1]

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Purpose: Military units have minimal tools to predict frostbite risk during cold weather operations. The resistance index of frostbite (RIF) has been used to determine frostbite risk and is calculated using responses obtained from a cold-induced vasodilation (CIVD) test. Physiological perception plays a role in how the body responds to cold stress, however, there is little evidence linking thermal sensation (TS) and pain sensation to RIF. The aim of this study was to evaluate the relationship between RIF strength, TS, and pain. Presence of a strong relationship may indicate a simple and effective technique for assessing frostbite risk. **Methods:** Thirty-two male military personnel (mean ± SD age: 22 ± 4 y; height: 1.74 ± 0.07 m; body mass: 77.1 ± 11.1 kg) completed a 30-min hand immersion in cold (8°C) water while indoors (22°C), followed by 10-min passive rewarming. Skin temperature was measured continuously on anterior pads of the index, middle, and ring fingers to assess CIVD components (onset time, minimum and mean finger temperatures), which were used to calculate an RIF score for each participant. TS and pain ratings of the hand were recorded every 2 min during immersion and recovery (30-min average calculated for analysis). For analysis, participants were grouped by RIF strength score: weak (3 to 4; n = 4), moderate (5 to 7; n = 25), and strong (8 to 9; n = 3). One-way ANOVAs were used to compare TS and pain sensations between RIF groups during immersion and rewarming ($p < 0.05$). Effect size was calculated to determine the strength of the sample size for each group (weak and moderate, moderate and strong, weak and strong). **Results:** Mean ± SD RIF scores for the three groups were: weak (4.0 ± 0.0; Cohen's d = −0.87), moderate (6.0 ± 0.8; Cohen's d = −0.85), and strong (8.3 ± 0.6; Cohen's d = −0.85). TS (weak: −2.9 ± 0.9, moderate: −2.5 ± 1.1, strong: −2.3 ± 1.3, $p = 0.757$) and pain (weak: 3.6 ± 3.6, moderate: 2.1 ± 1.8, strong: 1.6 ± 1.2, $p = 0.359$) were not different among groups during immersion. However, during rewarming, the weak group had colder TS (weak: −1.7 ± 1.0, moderate: −0.3 ± 1.0, strong: −0.2 ± 1.0, $p = 0.029$) and higher pain ratings (weak: 2.1 ± 2.8, moderate: 0.3 ± 0.7, strong: 0.0 ± 0.1, $p < 0.01$). **Conclusions:** Pain and TS responses were similar among RIF groups during immersion but may be useful to evaluate frostbite risk during rewarming. **Military Impact:** The use of perception to evaluate frostbite risk following localised cold exposure may have utility in military field settings, as implementation is simple and may allow for better identification and prevention of cold weather injuries.

Board 37: Effect of single versus twice daily heat acclimatisation on 5 km running performance in tropical native soldiers

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Purpose: This study aimed to compare the effects of twice-daily (TDHA) versus once-daily (ODHA) heat acclimatisation (HA) on heat adaptations and 5-km running time trial (TT) performance in warm, humid conditions. **Methods:** Thirty-two Singaporean male soldiers were matched and assigned to TDHA (mean ± SD) (BMI 23.4 ± 5.7 kg·m-2, TT timing 1,647 ± 162 s) or ODHA (BMI 23.5 ± 2.8 kg·m-2, TT timing 1,728 ± 204 s). Participants completed two five-day blocks of HA over two weeks, with either one or two sessions of moderate-strenuous physical activities lasting > 45 min per session. A pre-, mid-, and post-intervention TT and day 1, 5, 8, and 10 heat stress test (HST, 3-km run at 8 km·h-1) was completed in warm, humid conditions. Body temperature (Tc), heart rate (HR), sweat loss and electrolytes, ratings of perceived exertion (RPE), thermal comfort (TC), and thermal sensation (TS) were measured during the TTs and HSTs. **Results:** Post-intervention resting Tc in TDHA (36.86 ± 0.41°C, $p < 0.05$), but not ODHA (37.06 ± 0.23°C, $p > 0.05$; −0.23°C), was significantly reduced compared with the pre-intervention resting Tc (TDHA 37.21 ± 0.23°C; ODHA 37.29 ± 0.26°C). Mean exercising HR was significantly reduced across the HSTs in both ODHA (−25 ± 13 b·min^{-1}, $p < 0.01$) and TDHA (−21 ± 12 b·min-1, $p < 0.01$). Although TT performance was similar between groups at any time point (p <

0.05), their TT performances were improved across time (TDHA −110 ± 108 s, $p < 0.05$; ODHA −102 ± 104 s, $p < 0.05$). Pre-exercise HR, perceptual measurements, sweat loss, and electrolytes concentrations level remain generally unchanged. Training load in the TDHA group (184 to 615 au) was significantly higher than the ODHA group (88 to 467 au, $p < 0.05$) in all days, except for day 8 and 9. **Conclusions:** Both ODHA and TDHA effectively expanded heat capacity and reduced physiological and heat strain among tropical native soldiers during exercise in hot conditions. TDHA led to a greater degree of heat adaptation compared with ODHA. A 7-day TDHA will be sufficient to elicit the same degree of decline in resting Tc from a 10-day ODHA. **Military Impact:** Despite the additional thermoregulatory and training load induced by TDHA, a 7-day TDHA may be more feasible for established schedules due to lesser disruption while maintaining training quality and preventing heat-related illnesses.

Board 38: Neurobiomarker responses to thermal stress with physical activity: prior endurance exercise may confound mTBI diagnosis using UCHL1

Mike Stacey [1], Amanda Barden [2], Daniel Snape [3], Barney Wainwright [3], Yannis Pitsiladis [4], John P O'Hara [3], David Woods [1]

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Purpose: This study investigated how exercise and heat stress may affect the neurobiomarkers Glial fibrillary acid protein (GFAP) and ubiquitin carboxyl-terminal hydrolase isozyme L1 (UCHL1). Both are assayed in plasma by a semi-quantitative cartridge-based system (Abbott iSTAT Alinity®) that is FDA-approved to 'rule in' mild Traumatic Brain Injury (mTBI) following head trauma. We hypothesised that healthy volunteers would show unchanging levels across exercise bouts differing by mode, duration, environmental conditions and heat acclimation (HA) status. We further investigated the frequency with which the manufacturer's decision thresholds for suspecting more severe brain injury might be breached by neurobiomarker response to exercise-heat stress. **Methods:** Twenty endurance trained volunteers (five women, 15 men; age 30 ± 7 y, VO2max 56 ± 10 $mL{\cdot}kg{\cdot}min^{-1}$) were sampled for blood before and after cycle ergometry in a heated chamber (45 min at 2.0 to 2.5 $W{\cdot}kg^{-1}$ in 32°C), at un-adapted baseline and again following eight days of HA or control activity (combined exercise-hot water immersion regimen, n = 10 vs matched temperate exercise, n = 10). Separately, 50 unacclimatised runners (nine women, 39 men; age 31 ± 5 years) gave blood at rested baseline and after running the Brighton marathon 2022 (finishing time 3 h 59 min ± 49 min; peak ambient temperature 11 °C). In each study, body core temperature (Tc) was recorded (rectal thermistor vs BodyCap® telemetry pill), change in body mass was measured, and blood collected and centrifuged within 30 min post-exposure. A single accredited laboratory received frozen samples for analysis of thawed plasma by both benchtop ELISA (BENCH) and iSTAT Alinity (CARTRIDGE). **Results:** Cycling in the heat resulted in significant ($p < 0.05$) overall change in body mass (–1.41 ± 0.39 kg) and Tc (+ 1.5 ± 0.4 °C). No change in neurobiomarkers was observed by BENCH or CARTRIDGE, neither did HA status influence levels (p = 0.94) despite reduced Tc and increased sweat losses. CARTRIDGE decision thresholds for GFAP (30 pg·mL^{-1}) and UCHL1 (360 30 pg·mL^{-1}) were not exceeded. In the marathon, significant change in body mass (−1.39 ± 1.72 kg) and Tc (+ 1.8 ± 0.6 °C) were observed. Versus baseline, GFAP did not vary, whereas UCH-L1 increased for both BENCH (64.9 [39.1, 578.1] vs 91.0 [39.1, 570.0] pg·mL^{-1}, p = 0.0018) and CARTRIDGE (200 [200, 200] vs 448 [303, 756 pg·mL^{-1}, p < 0.0001). The CARTRIDGE decision threshold was not breached for GFAP but was exceeded for UCHL1 in 32/50 runners (highest value 2261 pg·mL^{-1}, reportable range 200 to 3200 pg·mL^{-1}). Conclusions: Neurobiomarkers used in mTBI assessment were unaffected by moderate intensity and duration cycling in the heat, with HA status having no discernible impact. However, prolonged running in cool weather conditions elevated UCHL1 above the decision threshold used in mTBI assessment. Military Impact: These results suggest caution in interpreting elevated UCHL1 after prolonged exercise.

Board 39: Assessing the predictive value of body surface area to mass ratio for heat intolerance in military personnel: a retrospective cohort study

Inbal Akavian [1], Alexandra Rabotin [2], Shiraz Peretz [3], Yoram Epstein [4], Itay Ketko [1]

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Purpose: Exertional heat illness (EHI) is a clinical condition that can occur in athletes and military personnel engaging in physical activity. At the extreme, EHI is presented as exertional heat stroke (EHS), which can be a life-threatening condition. Heat tolerance testing (HTT) is commonly used to evaluate an individual's ability to tolerate heat stress and is commonly advised for those who recover from EHI, as part of the return to duty decision making process. The body's ability to dissipate heat during exercise depends on several factors, including body anthropometry. The body surface area-to-mass ratio (BSA/m) is one such factor that has been studied as a potential predictor of heat tolerability. In this study, we aimed to analyse the potential predictive role of BSA/m in the HTT results. **Methods:** 523 records of young (age: 18 to 21 y) soldiers who were diagnosed with EHI and underwent a HTT were analysed and classified as heat tolerant (HT) or heat intolerant (HI) according to the dynamics in rectal temperature during the test. BSA/m was calculated for each participant. The BSA/m ratio was compared between HI and HT groups using a t-test, and logistic regression was performed yielding an odds ratio with 95% CI. **Results**: From the total cohort of 523 records, 50 soldiers were classified as HI and 473 as HT. The HI group had a significantly higher mean body mass compared with the HT group (78.6 ± 13.9 kg *vs* 73.0 ± 10.5 kg, p = 0.004), but there was no significant difference in height (HI: 1.75 ± 0.07 m *vs* HT: 1.76 ± 0.07 m, p = 0.21). The mean BSA/m ratio was significantly lower in the HI group (251 ± 21 cm^{-2}·kg^{-1} *vs* 259 ± 19 cm^{-2}·kg^{1} p = 0.005). The odds ratio for HI for each unit increment in BSA/m was 1.02 (95% CI: 0.96, 0.99). **Conclusions:** Heat intolerant individuals had a significantly lower mean BSA/m compared with heat tolerant individuals and odds of being heat intolerant increased with each unit decrease in BSA/m. Consequently,

positive HTT results should be assessed carefully—not only by simply identifying an individual as heat intolerant, but also by understanding the reason for the diagnosis. When no other intrinsic or extrinsic factor can explain heat intolerance in the HTT, a low BSA/m can be the underlying factor. **Military Impact:** The results of our study have implications for clinical decision-making and management of soldiers who have suffered EHI. The findings may help in developing decision-supportive tools for assessing heat tolerability before soldiers return to duty.

Board 40: Impact of 12 km military march on skin temperature using infrared thermography

Fernando A Santa Rosa [1], Samuel Nardello Pontel[2], Issac Silva Santos[2], Matheus Simões Mendes[2], Eduardo Borba Neves[3], Rodrigo Gomes De Souza Vale [4], Manuel Sillero-Quintana [5], Danielli Mello [2]

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Purpose: Marching is one of the activities performed by soldiers for tactical or administrative displacement. Under normal conditions, carried mass (uniform, ballistic vest, helmet, backpack, jacket, pants, boot, weapon, specialised equipment, and supplies) can reach 35 kg over long distances. Lower limb muscles are adapted for weight-bearing and repetitive movement, and in the marching are crucial for providing stability, support, propulsion, endurance, and coordination. Understanding muscle and metabolic behaviour of lower limbs are necessary for injury and risk prevention. The aim of this study was to analyse skin temperature (T_{sk}) of Brazilian soldiers before and after a 12 km march with added load (30 kg) by IRT. **Methods:** Descriptive transversal study with 16 male soldiers (28.3 ± 3.2 y, 1.79 ± 0.07 m, 81.7 ± 8.6 kg), during a 12 km simulated march, in a laboratory treadmill at 5.2 km·hT_{sk} for 140 min in a thermoneutral environment (22.8 ± 0.19°C; 62.5 ± 0.95%). T_{sk} was assessed by infrared camera E75 FLIR® on lower limbs regions of interest (ROIs) (thigh, adductor, knee / Popliteus, leg, ankle / Achilles, and feet) in the anterior (AV) and posterior views (PV) at two moments: pre- and post-march. Thermograms were processed by ThermoHuman®. It was also measured the core temperature (T_{core}) by BodyCAP®, heart rate (HR) by Polar V800, and perceived effort by Borg RPE for safety control. Data were analysed by SPSS® 27.0 using the Student's t-test. **Results:** T_{core}, HR, and RPE were 37.08 ± 0.12°C, 128 ± 12 b·min-1, and 4 to 5. No asymmetry was identified between the right I and left (L) side in AV and PV. ROIs thigh, knee / Popliteus, and leg showed a significant ($p \leq 0.05$) increase in temperature at R and L side in AV and PV. But the most affect ROIs (%Δ) were: R ankle (2.81; $p \leq 0.001$); L ankle (2.61; $p = 0.001$); R Achilles (2.69; $p \leq 0.001$); L Achilles (2.76; $p = 0.001$; R anterior feet (4.31; $p \leq 0.001$); L anterior feet (3.92; p = 0,001); R posterior feet (4.20; $p \leq 0.001$) and L posterior feet (4.03; $p = 0.001$). **Conclusions:** T_{sk} of ankle, Achilles, and feet were the most affected by the military march, probably due to the material and inefficiency of cooling these boots. T_{sk} increase may be related to inflammation, circulation, nerve-overuse, and related injuries, and IRT could be a non-invasive option for preventing musculoskeletal injuries. **Military Impact:** Preventing, treating, and managing such injuries is crucial for maintaining military effectiveness, combat readiness, physical performance, and soldiers' overall health for a stronger and more effective military force capable of meeting the challenges of modern warfare.

Board 41: Thermoregulatory model validation of physical readiness training guidance to prevent cold-weather injuries

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Purpose: Guidance for reducing the risk of cold-weather injuries is sparse, especially during exercise. For example, the wind chill temperature (WCT) does not account for soldier's metabolic rate during physical readiness training (PRT) and provides little information on clothing choices. The aim of this study was to investigate current PRT clothing guidance for cold weather injury prevention using thermoregulatory models during exercise in the cold at different metabolic rates in men and women. **Methods:** The Cold-Weather Ensemble Decision Aid was used to run multiple simulations at different air temperatures (range: 0° to −32°C) and PRT clothing ensembles at 2 metabolic rates in men and women. Simulations were based on the Cold Weather PRT Policy from 11th Airborne Division, Alaska. Clothing guidance in this policy is general and is similar between women and men. Female characteristics were: body mass 69 kg; height 1.63 m, and; body fat, 28%. Male characteristics were: body mass, 85 kg; height 1.75 m, and; body fat 21%. Metabolic rates were 293 W and 768 W for women and 366 W and 946 W for men at walking and jogging speeds of 1.34 and 2.68 m·s-1, respectively. **Results:** Model simulations showed that skin temperatures were well within safe limits (> 8°C) for the risk of hand / foot frostbite at both metabolic rates. Model simulations did identify differences between men and women. At 0°C and walking, estimated hand skin temperatures (Thand) were ~ 2.3°C higher in women compared with men; at the jogging pace, Thand in women was 4°C higher after 2 hours of exercise, and estimated foot skin temperatures (Tfoot) were 1.5°C higher in women than men. However, at −12°C, men had ~1.0°C higher Thand and 1.2°C higher Tfoot while walking. Comparisons were also made, during walking, at different combinations of air temperature and wind speed equalling the same WCT. Thand was 9.6°C at a −26.1°C air temperature and 4.5 m·s-1 wind speed (equals −37.2°C WCT), while wearing PRT clothing recommended for −26.1°C conditions. In comparison, Thand was 16.6°C at the −37.2°C air temperature with no wind. **Conclusions:** Evaluating clothing guidance with the use of thermoregulatory modelling at air temperatures ranging from 0° to −32°C demonstrated that current PRT guidance protects female and male soldiers against frostbite risk over a 2-h time period. Comparisons across different environmental conditions eliciting similar WCTs suggest that clothing ensembles be chosen based on the WCT value rather than the absolute air temperature. **Military Impact:** Current PRT clothing guidance for a range of cold air temperatures protects against cold injury risk in Alaska. Similar guidance could be adopted for other cold-weather areas.

Board 42: Cognitive assessment during heat tolerance test (HTT) of combat soldiers post exertional heat injury

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Purpose: According to the Israel Defense Forces (IDF) regulations, every soldier who suffers an exertional heat injury (EHI) must perform a heat tolerance test (HTT) as part of the clearance for return to duty. The criteria to determine the tolerance to heat are based solely on physiological parameters, while no cognitive or psychological evaluation is considered. The study aimed to add a cognitive evaluation to the physiological parameters monitored in the HTT and evaluate the correlation and the role of cognitive performance and mood states with the physiological parameters for a better diagnosis of heat intolerance. **Methods:** Seventy post EHI participants, performed the IDF HTT (treadmill: 5 km·h-1 and 2% elevation at 40°C and 40% relative humidity). During the HTT participants were continuously monitored for body core (Trec) temperature, skin temperatures, and heart rate, and underwent assessment of perceived exertion (RPE), cognitive function (psychomotor vigilance test, PVT), and psychological strain using computerised tests and a profile of mood states (POMS) questionnaire, at 0, 60, and 120 min of the HTT. Trec, physiological strain index (PSI), RPE, and cognitive performance measures were compared between heat intolerant (HI) and heat tolerant (HT) groups using t-tests. Differences over time were analysed using repeated measures ANOVA. **Results:** According to the physiological criteria, 56 participants were diagnosed as HT and 14 as HI. The HI group presented higher Trec and PSI ($p < 0.05$) compared with the HT during the second half (60 to 120 min) of the HTT and a higher RPE during the test ($p < 0.05$). The mean score for mood disturbance was significantly higher ($p < 0.05$) among the HI compared to the HT group at all time points. The HI group showed a decrease in cognitive performance after 60 and 120 min of the HTT. Mean response time was significantly longer among the HI compared with the HT after 60 and 120 min ($p < 0.05$). **Conclusions:** The RPE and PVT results significantly differed between HI and HT during the HTT but not at baseline. The adverse effects of heat stress on cognitive performance and mood state during HTT was lower for HT than HI participants. **Military Impact:** Cognitive assessment can augment commonly used physiological criteria for heat intolerance diagnosis in the HTT, with implications of the return to duty decision.

Board 43: Is there an anthropometric bias in the heat tolerance test? Exploring heat intolerance further with a human conceptual heat balance approach

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Purpose: Heat intolerance is defined as the inability to maintain a thermal balance whereas other individuals are able to do so under the same conditions. Thus, being intolerant leads to a higher risk of developing heat stroke. In the military, the heat tolerance test (HTT) is usually

performed to classify individuals who have suffered exertional heat stroke, as heat tolerant or intolerant, prior to their return to duty. The study conceptually examined the HTT physiological compensability regardless of the anthropometry of the individuals. Then, the sweat rates required to reach thermal balance were estimated to go further into the interpretation of the HTT results. **Methods:** The HTT consists of walking for 2 h on a treadmill, at 5 km·h^{-1}, with a 2% slope, at a temperature of 40°C and 40% relative humidity. All the elements of the heat balance equation were calculated. Metabolic heat production was predicted using the Lankford equation. Then, the evaporative requirement for heat balance, the maximum evaporative rate possible and the predicted sweat rate were estimated for different body mass (55 to 100 kg) and body mass index ([BMI] 24, 27, and 30 kg·m^{-2}). **Results:** Skin wetness required for heat balance increased with mass and, for a given mass, increased with BMI. However, regardless of body mass and BMI, the conditions are physiologically compensable, provided people are endurance trained (skin wetness is comprised between 0.64 and 0.75). Metabolic heat production and evaporative heat requirements are similar across masses and BMIs (when expressed relative to body mass and surface area, respectively). Predicted sweat rates varied by up to 100% according to mass and the sweating efficiency selected. For example, the sweating rate determined by the skin wetness was about 500 and 1000 g·h-1 for a 55 and 100 kg person, respectively. **Conclusions:** Skin wetness indicates that the HTT is theoretically physiologically compensable regardless of individual anthropometry. However, a skin wetness greater than 0.7 indicates that participants must be endurance trained to have the ability to secrete sweat at a sufficient rate to reach thermal balance. Furthermore, since individual variations in rectal temperature changes are primarily influenced by metabolic heat production expressed relative to body mass, our results support the possibility of comparing rectal temperature changes during the HTT between individuals of different masses. Finally, predictions of the required sweat rates allow further interpretation of the HTT results. Indeed, if heat intolerance is detected, the comparison of observed sweat rates with the estimated rates can help distinguish the organic intolerances from the temporary functional intolerances: an organic defect of thermolysis would lead to a much lower rate and an excessive thermogenesis would lead to a much higher rate than the predicted sweat rate. **Military Impact:** Ultimately, our objective is to determine whether the heat intolerance revealed by the HTT is of organic or functional origin.

Board 44: Impact of acute and habitual caffeine consumption on local tolerance to cold after total sleep deprivation

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Purpose: Fatigue and sleep deprivation have been empirically identified as individual risk factors for cold injuries. Caffeine is the main countermeasure used to mitigate effect of sleep debt. The aim of this study was to assess the impact of acute caffeine intake on local tolerance too cold during total sleep deprivation, according to habitual caffeine consumption. **Methods:**

Thirty-six healthy participants (age 38 ± 2 y, 16 men) followed two total sleep deprivation (TSD) in laboratory protocols (38 h awakening) with cross-over treatment (caffeine vs placebo). We assessed using a linear mixed model influences of acute caffeine (2×2.5 mg·kg·day^{-1}) treatment and habitual caffeine consumption, on fingers (index and annular) temperature and skin blood flow (SkBf) during cold-water immersion (CWI, 5°C, 20-min) and passive 20-min recovery in ambient air (22°C). **Results:** We didn't observe a significant effect of TSD on fingers' temperature during immersion, but confirmed, during recovery, a drop of temperature (27.2 ± 0.5 vs 25.7 ± 0.5°C, $p < 0.05$), cutaneous perfusion (−20.2 ± 9.6 %, $p < 0.05$), and dispersion (+80.8 ± 20.6 %, $p < 0.05$) (Laser Speckle measurements). Acute caffeine increased minimum finger temperature during immersion (9.1 ± 0.5 vs 8.7 ± 0.5°C, $p < 0.05$) and improved recovery compared with placebo. It also has a beneficial effect on pain during immersion before TSD ($p < 0.05$). We showed interactions with habitual caffeine consumption: low caffeine consumers (50 mg·day^{-1}) had higher skin temperatures (*i.e.*, mean plus min) during immersion than high consumers (>300 mg·day^{-1}). **Conclusions:** Acute caffeine intake could be a protective countermeasure to the local cold response, especially during TSD. However, habitual chronic consumption diminishes this beneficial effect. Caffeine intake is an individual variability factor that should be recorded during cold water immersion protocols. **Military Impact:** We give some recommendations for caffeine consumption in military cold environment. Acute caffeine intake is a protective countermeasure during local cold exposure. However high habitual caffeine consumption decrease tolerance to cold.

Board 45: Managing heat stress: from science to practical implementation

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Purpose: The combination of hard physical work, high clothing insulation, and hot climates—often encountered in military working environments—can lead to a high body temperature and thus heat stress. The results are loss of performance and, in particular, a risk of serious exertional heat illnesses (heat exhaustion and exertional heat stroke, EHS). Although scientific research constantly identifies influencing factors (PubMed: 10,736 publications; 2013-2023; heat stress or heat illness) and clarifies their link(s) to heat stress related hazards, exemplary data from the US Army proves that it is a continuing problem. Apparently, the chain of effects from scientific research to prevention is not closed. How can scientific knowledge be implemented to manage heat stress effectively in a military setting? **Methods:** The scientific recommendations for NATO medical personnel on heat stress were updated by selective literature research in PubMed, including current civilian occupational guidelines, guidance-sets, and references. On this basis, suggestions for managing heat stress were compiled. **Results:** Heat stress management should avoid threatening conditions with a four-part approach: 1. Comprehensive sensitisation: educate all military personnel about the threat of heat stress, starting with the command level. 2. Information and training: science-based, digitally available information media, such as educational films, pocket maps, and flyers, in conjunction with training events, should support troops in implementing and adapting suitable measures independently. In addition to preventive measures, like physical fitness, acclimatisation, and behaviour in the heat, recognition of heat-emergencies and their immediate treatment is also essential (EHS: golden half-hour). 3. Climate assessment: provide troops with a daily updated climate assessment by meteorological facilities—including a thermal index (weather forecast)—and with the ability to carry out their own current climate measurement on site (mobile climate measuring devices) for risk assessment and planning. 4. Long-term further research: further research is needed for the special military setting, in particular, to identify military jobs with high heat stress and to develop targeted solutions (*e.g.*, microclimate cooling systems for crews of overheated protected vehicles). **Conclusions:** In this way, training and missions can be planned, especially by adjusting physical work (marching speed, loads) and clothing insulation or by time shifting depending on the weather and defining the plannable framework conditions (*e.g.*, sufficient liquid supply). **Military Impact:** The cross-linked implementation of these four measures can reduce the loss of performance and the risk of exertional heat illnesses.

Board 46: Individual vulnerability to hypoxia: impact of an HMOX2 single nucleotide polymorphism on chemosensitivity in Caucasians

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Purpose: In the course of their missions or training, military personnel are regularly exposed to altitude hypoxia. The first physiological response is hyperventilation. Above 3,500 m, the acute hypoxia effects are not completely compensated, maladaptive responses occur, and individuals may develop acute mountain sickness (AMS). The incidence of AMS varies between 40% and 90%, depending on extrinsic factors and individual susceptibility. Thus, altitude hypoxia can impact military health and operational capacity depending on individual variability, linked in part to genetic factors. Recently, a functional genetic polymorphism in Heme oxygenase-2 (HMOX2, rs4786504_T>C), an essential enzyme in heme catabolism, has been associated with high-altitude adaptation in Tibetans. In the carotid body, heme oxygenase-2 is sensitive to oxygen availability and mediates the hypoxic response inducing increased breathing, which is different between individuals and linked to tolerance. We hypothesised that HMOX2 polymorphism influenced the chemosensitivity related to hypoxic ventilatory response (HVR) in Caucasians. **Methods:** The HVR ($FiO_2 = 0.115$) was measured at rest and submaximal exercise (30% maximal oxygen uptake) (the Richalet's test). Among chemosensitivity parameters, HVR at exercise (HVRe) is considered the best independent predictor of high-altitude tolerance. Low chemoresponsiveness was defined when HVRe < 0.78 $L \cdot min^{-1} \cdot kg^{-1}$ and high chemoresponsiveness when HVRe ≥ 0.78 L·min-1·kg-1. The LAMP-MC technology was used to determinate HMOX2 polymorphism. **Results:** 84 healthy participants were included with 47.6 % homozygous C/C, 41.7 % heterozygous C/T, and 10.7 % homozygous ancestral T/T. The C/T and T/T were grouped for analysis. HVR was significantly higher for C/C participants than for T allele carriers at rest (0.78 ± 1.16 vs 0.38 ± 0.405 $L{\cdot}min^{-1}{\cdot}kg^{-1}$, respectively, $p = 0.043$, $F = 4.22$) and exercise (0.736 ± 0.470 vs 0.534 ± 0.426 $L{\cdot}min^{-1}{\cdot}kg^{-1}$, $p = 0.042$, $F = 4.36$). A high HVRe was more frequent in participants carrying C/C polymorphism vs T allele ($p = 0.002$, OR = 5.2 [1.69, 16.03]). **Conclusions:** In our population, there is a significant association between HMOX2 polymorphism and chemosensitivity evaluated by HVR at rest and exercise. Although significant, this finding must be confirmed in larger samples. This may help to better understand the role of genetic factors in chemosensitivity, the first step in the hypoxia response. **Military Impact:** A better knowledge and understanding of the intrinsic genetic factors involved in individual responses to hypoxia are essential for prediction and prevention. They will allow the personalisation of recommendations and countermeasures in order to preserve the military health and operational capacity at altitude.

Board 47: History of freezing cold injury is associated with persistent decrease in local response to cold: a case control study

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Purpose: Freezing cold injuries (FCI) are lesions caused by prolonged exposure to a cold environment. This study investigated the link between history of frostbite and response to a cold hand test. **Methods:** Male participants (n = 40) were divided into two groups: a control group (n = 20) and participants with a history of FCI (n = 20). After a 30 min baseline, the right hand was immersed in cold water (Twater = 5°C) for 30 mins (Twater = 5°C) while inside a climate controlled chamber (22 ± 1°C, relative humidity 30% ± 40%), then underwent a 30 min passive recovery, and a 43°C active recovery phase. Anatomical metrics such as hand size, body mass, and age, were obtained at selection. Venous blood samples were taken at 5 stages (baseline, onset, CIVD [Cold Induced Vasodilation], passive recovery, and active recovery [43°C]) of the experiment. Cutaneous temperatures were monitored at the distal phalanges of the right hand. Results are expressed as mean ± standard deviation. **Results:** Thermal responses showed a significant difference at the recovery stage (Tpassivecontrol = 23.6 ± 0.7°C, Tpassivefrostbite = 20.5 ± 0.7°C, $p < 0.001$). Endothelin was higher for frostbitten vs control participants (1.03 ± 0.26 vs 0.78 ± 0.26 $pg{\cdot}mL^{-1}$ at baseline, 1.0 ± 0.29 *vs* 0.7 ± 0.24 $pg{\cdot}mL^{-1}$ at onset, 0.91 ± 0.29 *vs* 0.63 ± 0.27 $pg{\cdot}mL^{-1}$ at CIVD, $p < 0.01$). Differences in pain levels were reported between frostbitten and control (5.1 ± 2.1 vs 4.0 ± 2.0 at CIVD). Frostbitten participants gave, on average, higher pain scores than control. No relevant differences in anatomical features were found when comparing injured and uninjured participants. **Conclusions:** Our study shows that participants with FCI displayed a difference in their response, had attenuated environmental rewarming, expressed higher pain scores during the exposure, and had a higher concentration of a vasoconstrictive hormone, endothelin, both at baseline and throughout. Though no statistically significant

differences were found in the temperatures at immersion, the onset and CIVD stages were not separated. Immersive cold exposure provided an adequate simulation of environmental cold, this method displayed shortcomings in its ability to adequately monitor temperature changes. Aerial cold exposure, using a climate-controlled enclosure, and monitored with a thermal camera, would elucidate differences in responses and provide more realistic conditions. **Military Impact:** Understanding which military personnel are more prone to FCI would help protect them more adequately by identifying sensitive areas and vulnerabilities. Analysis of the hand's thermal kinetics would help design better thermal protections, such as heated gloves.

Board 48: Influence of skin temperature responses to cold water immersion as a predictor for cold shock response magnitude

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Purpose: Accidental cold water immersion (CWI) is a life-threatening emergency that can cause immediate drowning. Upon sudden CWI, a cascade of responses induced by activation of cold receptors is initiated and includes a large inspiratory gasp, tachycardia, vasoconstriction, hypertension, hyperventilation, intense sensations of cold / pain, and anxiety / panic (i.e., cold shock response [CSR]). Given that an abrupt reduction in skin temperature initiates CSR, it is hypothesised that larger reductions in skin temperature during CWI would induce greater magnitudes of tachycardia. The purpose was to evaluate the relationship between decrease in skin temperature and increase in heart rate (HR) increase during CWI in operational settings, with an overall goal of predicting tachycardia through skin temperature measurement during CWI. **Methods:** Eighty-two (n = 82) military personnel (age: 27 ± 5 y; height: 1.76 ± 0.08 m; body mass: 80.1 ± 11.4 kg) completed a field training exercise that included a 10-min CWI (1.5°C) in cold air (–4°C). Participants' HR, mean skin temperature (T_{sk}), and hand temperature (T_{hand}) were measured each minute before, during, and after CWI. For analysis, the difference in temperature from the minute immediately before CWI to the 5th min of CWI was calculated for T_{sk} and T_{hand}. Minimum temperatures for T_{sk} and T_{hand} obtained during CWI were also identified. The highest HR (HR_{peak}) was defined as the highest HR observed during CWI. Relationships between the change in T_{sk} and T_{hand}, as well as minimum T_{sk} and T_{hand}, were compared with HR_{peak} using Pearson correlations with significance at $p < 0.05$. Data are presented as mean ± SD. **Results:** CWI reduced T_{sk} and T_{hand} by 11.4 ± 3.1°C and 7.7 ± 3.7°C, respectively. Minimum temperatures for T_{sk} and T_{hand} were 12.1 ± 3.3°C and 8.3 ± 2.1°C, respectively. HR_{peak} was 136 ± 18 b·min-1. Weak correlations between HR_{peak} and change in T_{sk} ($r = 0.09$; $p = 0.41$) and change in T_{hand} ($r = –0.07$; $p = 0.51$) were observed. Additionally, weak correlations were observed between HR_{peak} and minimum T_{sk} (–0.07; $p = 0.53$) and minimum T_{hand} (–0.08; $p = 0.47$). **Conclusions:** Activation of CSR originates at skin temperature receptors, yet findings suggest that skin temperature reduction (absolute change and minimum temperature) upon sudden CWI poorly predicts tachycardia. **Military Impact:** Warfighters performing cold weather operations are susceptible to CWI and the physiological and health complications associated with CSR. Surrogate measurements other than skin temperature are necessary for determining CSR magnitude of

immersed warfighters.

Board 50: A comparison between a HR-based temperature algorithm and gastrointestinal temperature in military personnel during heat acclimation.

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Purpose: Soldiers often perform in challenging environmental conditions, causing a relatively high prevalence of exertional heat stroke. Heat acclimation induces physiological adaptations that optimally lead to a reduced risk of heat strain. Due to large individual differences in physiological adaptations, heat acclimation should preferably be individually monitored. To simultaneously heat acclimate large groups of soldiers, there is a need for a practical assessment of core temperature in an accurate way. Previous research showed that a HR-based temperature algorithm is capable of estimating core temperature with an accuracy of ± 0.6°C (limits of agreement) during walking, marching, or patrol simulating activities (Buller et al., 2013, Physiol Meas, 34, 781-798). Validity of the algorithm during heat acclimation using cycling has not been established yet. Therefore, this study compared the HR-based temperature algorithm to gastrointestinal temperature during heat acclimation during cycling exercise in soldiers. **Methods:** Twenty-three soldiers ranging in military background (four women, 19 men; age, 32.7 ± 8.8 y) completed a five-day acclimation protocol, by cycling at 1.5 $W \cdot kg^{-1}$ for 30 min followed by 60 min self-paced cycling in a climate regulated tent (35.1 ± 0.4°C and 52 ± 2% relative humidity). Mean core temperature between 20 and 30 min in the protocol was used to compare gastrointestinal temperature (via telemetric pill) and the HR-based algorithm. **Results:** The average temperature for both methods was 38.00˚C, with the difference between the two methods of 0.00 ± 0.33°C ($p = 0.925$). The average gastrointestinal temperature measured at day 1 to 5 was 38.10 ± 0.35°C, 38.05 ± 0.28°C, 37.96 ± 0.36°C, 37.97 ± 0.32°C, and 37.93 ± 0.27°C, respectively. For the HR-based temperature this was 38.08 ± 0.28°C, 38.04 ± 0.29°C, 38.01 ± 0.24°C, 37.96 ± 0.26°C, and 37.92 ± 0.24°C, respectively. No significant difference between days was observed for both methods ($p = 0.314$ and $p = 0.202$ for the gastrointestinal and the HR-based temperature respectively). Additionally, the limit of agreement was 0.65˚C. **Conclusions:** The core temperature estimated by a HR-based temperature algorithm during days of repeated cycling exercise was comparable to that of a telemetric pill measuring gastrointestinal temperature in military personnel. The limits of agreement were comparable to that of earlier reports. **Military Impact:** This study shows that a HR-based temperature algorithm can be used to monitor groups of soldiers with a reasonable accuracy performing cycling exercise during heat acclimation, which makes it easier to effectively acclimatise soldiers before operating in the heat.

Board 51: Thermal manikin tests of the multilayer thermal insulation of combat winter clothing

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Purpose: Soldiers on guard duty in a cold environment do not have the possibility to move much and therefore have low metabolic heat production. They need cold weather combat uniforms that provide good protection against the cold. This study aimed to define the variations of thermal properties of combat clothing ensembles. **Methods:** Three different cold weather combat clothing ensembles (HIGH, MED, and LOW) worn for guard duty were tested on a static thermal manikin placed in a climatic chamber with environmental condition of 10°C, 50% RH and 1.8 $m \cdot s^{-1}$. The norms used during the tests were ISO 9920 and ISO 15831. The uniforms were individually selected for a predefined climate and activity. A temperature sensor was placed on the back at the surface of each layer of clothing. Total thermal insulation was calculated by the temperature difference between the manikin body and the environment divided by the dry heat loss. The last layer for the three uniforms included in the measurement was a waterproof jacket (LOW), a synthetic waterproof fleece coat (MED), and a synthetic insulated jacket (HIGH). The original last layer for the HIGH ensemble were not included in the measurement on the manikin because its isolation impact on temperature is negligible (0.2°C). **Results:** The thermal insulation results for LOW, MED, and HIGH are 0.38 $m^2 \cdot K \cdot W^1$, 0.41 $m^2 \cdot K \cdot W^{-1}$, and 0.65 $m^2 \cdot K \cdot W^{-1}$, respectively. According to ISO 11079, the minimum required clothing insulation for standing guards is 0.43 $m^2 \cdot K \cdot W^{-1}$ at −10°C, 0.56 $m^2 \cdot K \cdot W^{-1}$ at −20°C, and 0.68 $m^2 \cdot K \cdot W^{-1}$ at −30°C. The temperature difference on the back between inside and outside of the last layer is 3°C (LOW), 1°C (MED), and 7°C (HIGH). **Conclusions:** The insulation of the LOW and MED uniforms are just slightly below what is recommended at –10°C and the HIGH uniform has sufficient isolation to be protective at –20°C during guard duty. The microclimate measurement shows the thermal properties of each garment in the uniform: the insulated jacket retains more heat inside than the waterproof jacket or the fleece coat. **Military Impact:** Joint training and operations capabilities can be limited by the large differences in insulating properties of clothing between allies. To know the thermal isolation of the cold weather combat uniforms could be of a high value in cold weather training and operations predicting if the soldiers are protected from cold weather injuries.

Board 52: Effect of a lightweight packable insulation blanket on body core and skin temperatures during passive exposure to –30°C: a pilot study

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Purpose: Soldiers getting wounded in arctic conditions may have to wait up to 3 h in immobile state for evacuation. During this period, an insulation blanket may help to prevent hypothermia and peripheral cold injury. The Blizzard BPRS-01 is a lightweight vacuum-packed survival blanket that aims to fulfil this task. The purpose of this explorative study was to evaluate its effectiveness to keep the body core and peripheral temperatures above harmful levels. **Methods:** Four participants were exposed to −30°C (dry air, 0.2 m·s-1) in a climate chamber for 2 × 60 min, with sufficient rewarming time in between. Three participants lay down on a mat, one sat in a chair. A standard winter outfit was worn in both sessions with the second session participants were additionally wrapped in the blanket. Body core temperature was measured by an ingestible pill, and skin temperatures were measured at the ventral middle finger and toe tip by thermocouples. Additionally, skin temperatures at the left hand and foot (dorsally) and at the chest were measured by iButtons, as well as microclimate temperature at the outer clothing layer of the upper body (i.e., underneath the blanket in session 2). Temperature values are expressed as median and range (lowest to highest). **Results:** Session 1 was stopped after 38 min (38 to 39) due to peripheral skin temperature getting dangerously low. Finger temperature dropped to 9.71°C (5.26 to 15.08), toe temperature to 9.35°C (6.87 to 12.62). Session 2 lasted the full 60 min, in which finger temperature dropped to 22.41°C (17.81 to 23.48) and toe temperature to 9.37°C (8.41 to 11.40). Drops in hand and foot temperature were more moderate, changes in chest skin temperature were small. Core temperature altered by only −0.09°C (−0.03 to 0.24) during session 1 and −0.35°C (−0.50 to −0.13) during session 2. Microclimate temperature increased from −19.21°C (−26.67 to −19.08) at session 1 to −0.37°C (−7.05 to 3.83) at session 2. **Conclusions:** The insulation blanket improves the microclimate around the body, reducing the drop in peripheral skin temperatures. However, toe temperature remains a concern that needs to be addressed. Meanwhile, proper clothing and metabolism can keep core temperature stable for at least 60 min in −30°C with no wind, irrespective of blanket. **Military Impact:** During cold weather (emergency) situations, peripheral rather than core temperature maintenance appears to be the major challenge. In addition to insulation blankets, military forces should seek for additional means (e.g., heating packs) to keep extremity temperature sufficiently warm for several hours, especially at the toes.

Board 53: Using axillary skin temperature to monitor core temperature in military scenarios: an exploratory investigation

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Purpose: Various wireless patches have been developed to monitor skin temperature, which aims to estimate core body temperature of workers including military personnel. Monitoring the core temperature of soldiers under heat stress is crucial in preventing heat-related disorders, but invasive measurements such as rectal temperature are not feasible in outdoor training. The present study aimed to explore the possibility whether the core body temperature could be estimated using axillary temperature in hot environments. **Methods:** Five participants (four males and one female) participated in a 60 min trial, which consisted of 10 min rest, followed by a 35 min Harvard step exercise, and a 15 min recovery at an air temperature of 33°C with the air humidity of 60% relative humidity. Participants were current or former soldiers and wore combat uniforms including combat boots. Axillary temperature (T_{ax}) using a wireless temperature patch (MT100D, Seers, Korea), rectal temperature (T_{re}), and skin temperatures on the eight body regions (LT-8A, Gram Corp., Japan) were measured every 5 s. The last 5 min values of each phase were averaged as the representative value of each phase. **Results:** Based on Bland Altman plots, the differences between T_{ax} and T_{re} during exercise and recovery were 0.98 ± 0.9°C (Mean ± 1.96SD) and 1.08 ± 1.07°C, respectively, while the average difference was 0.32 ± 0.98°C at rest. There was no significant difference between T_{ax} and T_{re} at rest (36.8 ± 0.3°C for T_{ax} and 37.0 ± 0.4°C for T_{re}), whereas T_{ax} was significantly lower than T_{re} during exercise (37.6 ± 0.6°C and 38.7 ± 0.3°C, $p < 0.05$) and recovery (38.0 ± 0.7°C and 38.9 ± 0.3°C, $p < 0.05$). No relationships between T_{ax} and T_{re} during both exercise and recovery were found. **Conclusions:** It is not recommended to use the axillary temperature to estimate soldiers' core body temperature during active military operations in hot environments. However, axillary temperature using the wireless patch sensor could be applied to estimate core body temperature when the soldiers are in static states (e.g., while resting or standing still) during hot summer. **Military Impact:** Soldiers, while doing surveillance in static positions or at rest in hot environments, could benefit from monitoring their armpit temperature to estimate core body temperature.

Thematic Sessions 16 to 19

Wednesday 13th September, 16:00 to 17:30

Thematic 16: Physiological consequences of arduous military energy deficits and the anabolic role of protein nutrition

Main Room

Description

This session will review the physiological consequences of energy deficits during military training and address the anabolic role of protein nutrition as a countermeasure for supporting musculoskeletal anabolism. Presentations will include a mechanistic summary outlining the negative physiological effects of energy deficits, novel findings from recent applied nutrition studies conducted across laboratory and military training settings, and remaining knowledge gaps. Following this session, attendees should be able to describe how energy deficiency during military training influences musculoskeletal responses and adaptations. They should also be able to understand the mechanistic evidence supporting targeted protein nutrition interventions to support musculoskeletal anabolism and counteract musculoskeletal tissue loss under stress.

Background

Military personnel frequently endure periods of high exercise-induced energy expenditure and inadequate energy intake during strenuous military training and operations. The resulting energy deficits and physiological responses dysregulates protein homeostasis—leading to reductions in whole-body protein retention, increased oxidation of dietary protein for energy, and suppressed whole-body and muscle protein synthesis—and bone metabolism. Increasing daily intake of dietary protein amount and quality during moderate energy deficit in non-military environments restores muscle protein synthesis rates to preserve lean mass. However, the efficacy of protein nutrition strategies for promoting musculoskeletal anabolism during military-specific scenarios of energy deficiency has additional logistical considerations (limited time or desire to eat, willingness or ability to carry rations) beyond protein quantity and quality. Therefore, developing protein-containing supplemental food products that deliver an optimal quantity and composition of protein within an easily digestible and absorbable food format has remained an area of military nutrition focus.

Military Impact

Energy deficits remain a prominent, and often unavoidable, problem across military training and operational environments. This session will provide attendees with a contemporary understanding of the consequences of energy deficit on musculoskeletal tissue and how protein nutrition may counteract these effects. Recent findings reporting the development and implementation of military-specific protein nutrition during scenarios of energy deficiency in the laboratory setting and real-world training environment will be presented. Collectively, the information covered in this session will highlight protein-based nutritional approaches for optimizing physiological and metabolic status and enhancing recovery during situations of operational stress. Outstanding knowledge gaps and opportunities for additional research will be highlighted including speaker perspectives for the way forward.

Presentations

Chair: *Jess Gwin, US Army Research Institute of Environmental Medicine, USA*

16:00 – 16:20: The physiological consequences of energy deficit in military training and employment

Thomas J O'Leary, Army Health and Performance Research, UK

16:20 – 16:40: Developing dietary protein feeding solutions to support anabolism during energy deficit: findings from the laboratory

Jess Gwin, US Army Research Institute of Environmental Medicine, USA

16:40 – 17:00: Nutritional strategies for muscle recovery and repair during energy deficits resulting from arctic military training

Emily Howard, US Army Research Institute of Environmental Medicine, USA

17:00 – 17:20: Protein supplementation and bone metabolism during military training in energy deficit

Charlotte V Coombs, Army Health and Performance Research, UK

17:20 – 17:30: Questions and discussion

Disclaimer: *The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Army or the Department of Defense. Any citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement of approval of the products or services of these organizations.*

Thematic 17: Survive and thrive in the cold

Room 1

Description

Geopolitics along with increased accessibility to the High North resulting from climate change, has led to many militaries renewing their focus on Arctic capability. Currently, military researchers have collaborated via the International Cooperative Engagement Program for Polar Research (ICE-PPR) and the North Atlantic Treaty Organization (NATO) Human Factors and Medicine (HFM) RTG-310 Panel. This thematic session provides an overview of the work undertaken by these groups to improve military performance in Arctic settings, ranging from the perennial problem of hand protection and dexterity, through international cold injury data collection, to behavioural cold adaptation through training.

Background

Throughout military history, wars have been lost by armies not prepared to fight in the cold. With an increased training tempo in the Arctic, where temperatures may reach –60°C, there is concern that operational performance is not assured and that there is significant risk of cold injury. It is not enough to just survive extreme cold, military forces must be able to perform their mission. Current military performance research continues to expand knowledge on energy expenditure and nutritional requirements, specialised clothing and protective equipment, effective training packages, and even genomics. However, research gaps still exist and the challenges for military personnel operating in extreme cold remain high. Clinicians and scientists need to work with a sense of urgency to further develop an evidence base that enhances practices in the cold to improve resilience and performance of troops, enabling them to 'survive and thrive in the cold.'

Military Impact

For several decades, western armies have been focused on operational effectiveness in dry heat in the desert. Now, nations are realising the need to re-equip themselves to perform effectively and prevent injury in the cold. It is imperative to develop strategies to prevent cold injury, maintain fighting capacity, and achieve operational success. Maintaining performance and avoiding injury in extreme cold is of paramount importance. Specialised technology such as cold protective equipment is important but useless without effective training in realistic conditions. More effective training is informed by understanding and mitigating cold injury risk factors and identifying and managing injuries. Military personnel have an ever-increasing burden of knowledge and skills to assimilate; thus, training packages must be founded on the best science and information that will improve survivability and performance.

Presentations

Chair: *Karl Friedl, US Army Research Institute of Environmental Medicine, USA: Hilde K Teien, Norwegian Defence Force, Norway*

16:00 – 16:12: Effect of cold weather combat clothing on peripheral skin temperatures and manual dexterity after exercise followed by passive standing in a sub-arctic climate

Julie Renberg, Norwegian Defence Research Establishment, Norway

16:12 – 16:24: Cold stress of Canadian military aircrew in a simulated survival scenario under Arctic winter conditions

Fethi Bouak, Defence Research and Development Canada, Canada

16:24 – 16:36: The importance of training for Arctic survival for Royal Canadian Air Force pilots

Wendy Sullivan-Kwantes, Defence Research and Development Canada, Canada

16:36 – 16:48: Fatigue and cognitive impairment during Canadian Armed Forces Army Arctic operations

Wendy Sullivan-Kwantes, Defence Research and Development Canada, Canada

16:48 – 17:00: Use of thermoregulatory models to predict cold injury risk

John W Castellani, US Army Research Institute of Environmental Medicine, USA

17:00 – 17:12: NATO Research Task Group 310: Cold weather injury tracking tool

Sarah Hollis, Ministry of Defence, UK

17:12 – 17:30: Questions and discussion

Thematic 18: Collaborative research on resilience across The Technical Cooperation Program member nations

Room 2

Description

This session highlights collaborative research by The Technical Cooperation Program (TTCP) Technical Panel 21 on resilience. TTCP supports collaborative military research across five countries (Australia, Canada, New Zealand, the UK, and the US). The first presentation focuses on results of applied research on identifying potential targets for resilience-building interventions for military personnel during the COVID-19 pandemic. The second presentation focuses on initiatives employed to build resilience among servicemembers transitioning out of the military. The third presentation addresses a targeted scoping review conducted to identify theoretical frameworks for considering context in the development and implementation of resilience training. The final presentation summarises adapting a training program to help soldiers manage acute stress in combat across various national contexts. Highlights and lessons learned from this collaborative research will be discussed.

Background

Resilience, as it applies to military personnel, has been broadly defined as the capacity of the individual, team, and organization to recover quickly, resist, and possibly even thrive in the face of stressors and adversity in garrison, training, and operational environments. A number of military organisations have implemented interventions to enhance servicemembers' resilience. Their success, however, requires a solid understanding of the complex interplay of individual, family, and organizational factors that shape individuals' capacity to face adversity and remain resilient, which may vary greatly across national contexts. In 2017, the TTCP Technical Panel 21 was established consisting of researchers from Australia, Canada, New Zealand, the UK, and the US, which has served as a key platform for undertaking international collaborative research on resilience. This work has been pivotal to identify common challenges and help advance solutions that can be applied to bolster psychological and physical resilience across the five nations.

Military Impact

This thematic session will share important highlights and lessons learned from research that has been conducted on various facets of resilience across TTCP nations, ultimately shedding light onto how to best address the needs of both servicemembers and organisations that play a role in developing and implementing resilience-building interventions for military personnel.

Applying a multi-national lens in this research has enabled each nation to validate its findings and arrive at a deeper understanding of the factors that might commonly, or distinctly, shape resilience and/or the outcomes of related interventions across diverse national contexts. This research is invaluable, not only because it can help identify the most pressing needs to address in resilience-building interventions, but also because it points to strategies that might be used to ensure contextual and implementation factors are considered when developing these interventions to optimise their efficacy.

Presentations

Chair: *Jennifer EC Lee, Department of National Defence, Canada*

16:00 – 16:20: Assessing military mental health during the pandemic: a five-country collaboration

Jennifer EC Lee, Department of National Defence, Canada

16:20 – 16:40: International perspectives and strategies for building resilience in the military-to-civilian transition

Julie Coulthard, Department of National Defence, Canada

16:40 – 17:00: Taking context and implementation into consideration in military resilience training: a five eyes integrated perspective

Deniz Fikretoglu, Defence Research and Development Canada, Canada

17:00 – 17:20: Adaptation of a peer-based intervention for acute stress reaction: lessons from five militaries

Heather McCuaig Edge, Department of National Defence, Canada

17:20 – 17:30: Questions and discussion

Amy Adler, Walter Reed Army Institute of Research, USA

Thematic 19: Human performance optimisation for the warfighter: keeping it simple in a complex age

Room 3

Description

This session will explore the concept of Human Performance Optimisation (HPO) and how strength and conditioning practitioners working with military personnel can use evidence-based strategies by which to develop the physiological, psychological, and cognitive performance of the warfighter. The session will firstly review the demands of the modern operational environment before providing an overview of HPO as conceptual framework. Following this, the session will discuss the evolution of the tactical athlete and highlight and evidence appropriate strategies that can be implemented to inform best-practice in regard to the delivery of physical training for the warfighter.

Background

For the past two decades, western Armed Forces have been almost continuously engaged in combat operations worldwide. Over this period, changes to the character of conflict, combined with technological advancements, have resulted in a contemporary operational environment that is arguably more volatile, uncertain, complex, and ambiguous than ever before. While the character of conflict may have changed, it fundamentally remains a human endeavour that places unique and intense physiological, psychological, and cognitive demands upon the warfighter. As a result, there has been an increased emphasis in both military and scientific circles on the concept of HPO. In addition, the concept of the tactical athlete as a categorisation for military personnel and those who work in extremis settings has developed within the professional strength and conditioning community. Therefore, the aim of the proposed thematic session will be to review the demands of the modern operational environment, consider the utility of HPO as a conceptual framework, and provide evidence-based recommendations to develop the physiological, psychological, and cognitive performance of the warfighter.

Military Impact

The concept of HPO represents a new holistic paradigm whose impact has the potential to extend beyond the military, with implications for those who work in extremis contexts and for whom performance truly matters. This thematic session will aim to bridge the gap between HPO theory and its practical application and provide strength and conditioning practitioners working with military populations evidence-based recommendations by which to optimise the physiological, psychological, and cognitive performance of the warfighter.

Presentations

Chair: *Jonpaul Nevin, Buckinghamshire New University, UK*

16:00 – 16:20: Human performance optimisation (HPO): the human advantage

Jonpaul Nevin, Buckinghamshire New University, UK

16:20 – 16:35: The evolution of the tactical athlete: past, present, and future

Colin Suffield, Royal Army Physical Training Corps, UK

16:35 – 16:55: Optimising physical readiness for ground close combat

Jonpaul Nevin, Buckinghamshire New University, UK

16:55 – 17:15: Developing non-cognitive psychological performance factors through a developmental systems approach

Martin Jones, Buckinghamshire New University, UK

17:15 – 17:30: Questions and discussion

Thematic Sessions 20 to 23

Wednesday 13th September, 18:00 to 19:30

Thematic 20: Considerations in programming physical training in a military environment

Main Room

Description

Carefully planned, periodised, and progressive physical fitness training can help soldiers to reach different required occupational task levels before missions and operations. In the present session, we will discuss optimal physical training for different subgroups (men vs women, high-fit vs low-fit, and women entering military service directly vs those who completed a pre-conditioning program prior to commencing their service), how to prepare for operations, and how to maintain physical fitness on operations. We will also discuss the importance of different components of physical fitness, such as endurance, muscle strength, and motor skills, for successful actions in ordered military tasks. While an abundance of research has been published regarding training, comparatively little research has addressed sex differences or the physiological considerations for women. With increasing numbers of women serving in military, we need to better understand their training and performance needs. Indeed, several research paradigms that have yet to be explored.

Background

Physical training is the most effective method to improve or maintain physical performance. The outcome depends on training volume (duration, distance, or repetitions), intensity (load, velocity, or power), and frequency. When designing training plans in a military environment, one must first decide which factors to emphasise in order to meet the occupational requirements or deployment standards. It is also important that these emphasised training factors are well aligned with the trainee's individual needs and initial fitness level, and that the training plan is well programmed. Several factors such as age, sex, training history, recovery, sleep, and nutrition, as well as environmental, psychological, and social factors can significantly affect training adaptations. For optimising improvements in different components of physical fitness, such as endurance, strength, and motor skills, physiological sex differences should also be considered.

Military Impact

Military work involves a wide range of tasks involving carrying and lifting loads or additional loads. Advancement in urban centres and settlements requires intensive actions, such as short, fast, and anaerobic movements, and overcoming obstacles. Operations are conducted over large areas of depth with no clear front line. During operations and demanding manoeuvres, the operational capability of the force and the physical performance of individual combatants may deteriorate very rapidly. Generally, there is not sufficient time to improve physical performance or physical fitness during operations. Therefore, the physical performance of troops must be at a high level from the start of an operation, and they must be able to operate successfully both independently and at a group level.

Presentations

Chair: *Heikki Kyröläinen, National Defence University, Finland; Bradley C Nindl. University of Pittsburgh, USA*

18:00 – 18:15: Military physical preparedness for large scale combat operations (LSCO)

Bradley C Nindl, University of Pittsburgh, USA

18:15 – 18:30: Optimal physical training for improving performance in essential military tasks

Jani P Vaara, National Defence University, Finland

18:30 – 18:45: Strength training: basics and applications in a military environment

Heikki Kyröläinen, National Defence University, Finland

18:45 – 19:00: One size does not fit all: physical fitness responses to military training

Jace Drain, Defence Science and Technology Group, Australia

19:00 – 19:15: Perspectives on training strength and endurance concurrently in females

Ritva Mikkonen, University of Jyväskylä, Finland

19:15 – 19:30: Questions and discussion

Thematic 21: Reducing musculoskeletal injuries in the military: a consensus approach to tackling a shared wicked problem

Room 1

Description

This session will present the outcomes from an international consensus group's activity, which aimed to: develop methods for improving injury surveillance; identify a minimum dataset for retrospective data harmonising and prospective data collection; and thus inform military musculoskeletal injury (MSKI) research and mitigation programmes. The output from a Delphi study that was undertaken to develop a minimum reported MSKI dataset will be shared. Specific MSKI data analysis issues and common data errors will also be discussed to improve the confidence of data-informed decision-making. The findings from a scoping review on barriers and facilitators to military MSKI mitigation interventions will be presented. This will be followed by the results from a US-wide survey on barriers and facilitators to MSKI mitigation programmes to understand stakeholder views. In translating theory to practice, the session will consider the learnings for delivering effective and enduring military MSKI mitigation programmes and leveraging the necessary leadership prioritisation.

Background

Musculoskeletal injuries in military service members are an international problem, adversely impacting work, combat readiness, and national security. Musculoskeletal injuries are the leading causes for seeking healthcare/medical downgrade and medical discharge from service. In 2019, 53% of US soldiers had a MSKI, accounting for >10 million limited duty days. Similarly, MSKI accounts for circa 50% of UK medical discharges, and this rate has been consistent over the last 10-years. The average cost per injury of $2000 results in annual direct costs of >$3B across the US military. In 2018, the British Army projected a 10-year financial burden of >£1.6B from trainee and soldier MSKI. However, the full economic impact of MSKI in military populations remains unknown. The high injury incidence and long-term disability suffered from MSKI, and resulting financial burden, indicate that improved surveillance as well as scientifically robust and effective prevention strategies are urgently needed.

Military Impact

Increasing international threats necessitate a fit fighting force. There is shared urgency across allied partners to mitigate MSKI, maximise force generation, and optimise operational effectiveness. Nevertheless, there is a lack of international consensus on MSKI characterisation, injury surveillance methods, and programme reporting standards for military injury studies.

High-quality data are required to understand the problem, inform intervention development, and drive programme improvement. Moreover, whilst military injury mitigation and prevention programmes have demonstrated effectiveness in research trials, implementation and scalability in real-world settings have proved challenging. Barriers and facilitators to implementation have not been adequately assessed, nor have environmental and contextual factors that are required to inform programme delivery been appropriately summarised. This session aims to share insights for developing a collaborative approach to surveying, analysing, reporting, and using MSKI data to inform the development, implementation and evaluation of effective MSKI mitigation programmes in order to reduce MSKI occurrence.

Presentations

Chair: *Joanne L Fallowfield, Institute of Naval Medicine, UK*

18:00 – 18:12: Understanding the problem of musculoskeletal injuries in the military: an international consensus on musculoskeletal injury characterisation definitions, surveillance methods, minimal data collection, and reporting guidelines

Daniel Rhon, Uniformed Services University, USA

18:12 – 18:24: Data considerations for assessing musculoskeletal injury risk: greater clarity through more critical analyses

Nigel Arden, Oxford University, UK

18:24 – 18:36: Implementing effective musculoskeletal injury mitigation programmes: scoping review of barriers and facilitators

Sarah J de la Motte, Uniformed Services University, USA

18:36 – 18:48: Barriers and facilitators to musculoskeletal injury mitigation programmes: US survey

Garrett Bullock, Wake Forest University School of Medicine, USA

18:48 – 19:00: Delivering effective and enduring musculoskeletal injury mitigation programmes in the military: Translating barriers and threats to facilitators and opportunities

Ben Fisher, Defence Medical Services, UK

19:00 – 19:12: Why should leaders prioritise musculoskeletal injury mitigation? A rationale for re-balancing the operations-finances-people trade-offs

Joanne L Fallowfield, Institute of Naval Medicine, UK

19:12 – 19:30: Questions and discussion

Thematic 22: Exertional heat illness prevention: considerations for planning and real-time monitoring

Room 2

Description

NATO Panel HFM 237: Development of a NATO STANREC for Physiological Status Monitoring to Mitigate Exertional Heat Illness is addressing the risk assessment, planning, monitoring, and interpretation of real-time physiological status monitoring (PSM) feedback information as a valuable deployable asset for risk mitigation. The panel has been collating member nations policies and approaches to managing and preventing exertional heat illness (EHI) to assess for common themes and learning points. This session will provide a walk-through of the best practices in terms of risk assessment, risk reduction, risk management, and EHI prevention. The state-of-the-art in terms of the tools and technology available to the military, and how these could be deployed to assess, plan, and mitigate EHI risk, all within the context of a sensible national policy, will be presented.

Background

Military environments can pose a risk of EHI, especially when training is conducted in the heat and with heavy workloads and / or protective clothing ensembles. Assessing an individual's risk of EHI includes the integration of environmental factors (temperature, humidity, wind, and solar radiation), clothing characteristics, exercise intensity, and individual characteristics such as aerobic fitness, heat acclimatisation, and pre-existing conditions (e.g., viral infection, dehydration). Rather than trying to solve this complex integration problem a priori, the use of modern wearable sensors and real-time algorithms allows trainers and leadership to monitor an individual's physiological responses to exercise in the heat and directly assess their heat strain state and risk of EHI. Our NATO panel members have developed this combination of wearables and novel algorithms into functioning prototypes and successfully field tested these solutions. The use of PSM is becoming increasingly routine, but for ultimate success must fit into a greater risk assessment framework.

Military Impact

Exertional heat illness is one of the biggest risks currently facing warfighters and military commanders. Exertional heat illness can occur on a continuum from mild to severe, and in its more severe form can represent a risk to life. Costs to units in terms of risk mitigation efforts, lost training days, and reduction in readiness can be significant. Similarly, the cost to the individual can be catastrophic, including long-lasting medical issues and loss / change in career potential. Physiological status monitoring technology is at a point where the risk of EHI can be managed and reduced through proper monitoring and intervention. With low-cost wearable systems becoming increasingly available, it is hoped that the introduction of PSM systems in training will lead to a marked reduction in EHI, thus leading to an increase in unit lethality and readiness. The hope is that PSM systems will enable optimised training so units can train hard and train safe.

Presentations

Chair: *Mark Buller, US Army Research Institute of Environmental Medicine, USA*

18:00 – 18:05: Introduction to exertional heat illness prevention

Mark van Rijswick, Royal Netherlands Army, The Netherlands

18:05 – 18:19: Summary of exertional heat illness prevention policy: the glue

Brent Jones, Canadian Armed Forces, Canada

18:19 – 18:33: Risk assessment and risk reduction for heat illness prevention planning

Alison Fogarty, Department of Defence, Australia

18:33 – 18:47: Wearable technology and supporting algorithms for exertional heat illness detection

Mark Buller, US Army Research Institute of Environmental Medicine, USA

18:47 – 19:01: Dynamic risk management by wearable biosensors

Bertil Veenstra, Royal Netherlands Army, The Netherlands

19:01 – 19:15: Best practice: introducing physiological status monitoring policy into the military environment

Simon Delves, Institute of Naval Medicine, UK

19:15 – 19:30: Questions and discussion

Thematic 23: Fatigue and management of warfighter mental endurance

Room 3

Description

Members of NATO Human Factors Medicine working group (RTG-311) report findings from coordinated research on mental fatigue and countermeasures to sustain safe and effective military performance. The group's working definition of mental fatigue is a psychobiological state induced by prolonged exertion that has the potential to reduce performance. The combined presentations in this session will provide an alternative to current stove-piped approaches to fatigue problems in NATO forces, providing a new framework with which to address fatigue and endurance issues. The development of a new way of viewing the fatigue problem will permit more effective strategies to manage the problem, including more effective countermeasures in mission planning; individual and team endurance training strategies, and; new monitoring technologies that can be used to alert and enhance human endurance performance. The improved understanding of the basis for fatigue and endurance will provide insights into how to improve quality of man-machine interactions.

Background

Endurance has long been regarded in an overly simplistic fashion, considering only ability to perform with restricted sleep or high cognitive load, outpace others in prolonged continuous physical performance, or manage surveillance duties for an extended period of time without lapses. In fact, these factors are interrelated and endurance or "fatigue tolerance" is likely moderated through common mechanisms that reflect the net effect of all of these factors. For example, an extended cognitive load results in a subsequently reduced physical ability. Modern neurobiological technologies make it possible to map military risk factors for fatigue back to the common final pathways affecting brain and behaviour. Previous work by NATO RTG 260 developed common approaches to physiological monitoring of warfighter status; there is a need to extend this work to neuropsychological endurance, expanding technology for enhancing warfighter endurance through biofeedback and providing insights to autonomous systems to improve effectiveness of man-machine interactions.

Military Impact

Many mission failures and high visibility accidents are directly traceable to fatigue factors that result in errors of omission or errors of commission. The sources of fatigue are multifactorial including time on task for physical and mental workload, inadequate rest/sleep, circadian disruption, and even nutritional/metabolic limitations—factors that are commonly encountered in military operations and training. The basis for these effects on fatigue, or its opposite, endurance, are knowable from current advances in science and technology. Understanding the common neurobiological basis of endurance will provide insights into new neurophysiological monitoring strategies and fatigue countermeasures. Ability to monitor warfighter endurance will inform nonhuman systems about the status of human operators and allow automatic redistribution of workload and/or provide alerts to impending human error or failure. Strategies to extend warfighter endurance provide a substantial advantage to effectiveness and lethality.

Presentations

Chair: *Karl Friedl, US Army Research Institute of Environmental Medicine, USA*

18:00 – 18:12: Facial recognition of mental fatigue and application to switching cost capacity with a fire simulation task

Arnaud Rabat, Institut de recherché biomedicale des armees, France

18:12 – 18:24: Brain endurance training to enhance human performance: a systematic review and meta-analysis

Samuele Marcora, University of Bologna, Italy

18:24 – 18:36: Individualising modafinil use: cost-benefit profiling is the way to go!

Jeroen van Cutsem, Royal Military Academy, Belgium

18:36 – 18:48: A system for biometric monitoring and fatigue management for watch standing scheduling on a Navy ship

Rachel Markwald, Navy Health Research Center, USA

18:48 – 19:00: Numerical approaches for modelling of mental fatigue

Alexandre Lambert, Université Paris Cite, France

19:00 – 19:12: Can technology equal the ability of a trained leader to detect mental fatigue in soldiers?

Karl Friedl, US Army Research Institute of Environmental Medicine, USA

19:12 – 19:30: Questions and discussion

Oral Communication 14: Musculoskeletal Injury and Physiology

Thursday 14th September, 08:30 to 10:00

Main Room

Chair: *Tim Doyle, Macquarie University, Australia*

08:30 – 08:45: Lumbar spine injury risk during heavy load carriage when walking on slopes

Anne K Silverman [1], Jordan T Sturdy [1], Hedaya N Rizeq [2], Amy Silder [2], Pinata Sessoms [2]

[1]Colorado School of Mines, USA
[2]Naval Health Research Center, USA

Purpose: Carrying heavy backpacks and walking on sloped surfaces both require altered torso and pelvis postures relative to level, unloaded walking. Flexed postures combined with axial compression in the spine can create stress gradients in intervertebral discs that increase the risk of injury. Thus, the purpose of this study was to quantify lumbar joint contact forces during sloped and loaded walking while using different backpack implementations. **Methods:** Optical motion capture and ground reaction forces were collected from six participants while walking on −10° (Down), 0° (Level), and +10° (Up) slopes at 1.15 $m \cdot s^{-1}$. Each slope was performed with three load conditions, including wearing body armour and a helmet (NoPack) and two 40% body weight conditions, where the remaining mass was added to a backpack supported by shoulder straps only (Shoulder) or shoulder straps and a hip belt (HipBelt). We used a full body musculoskeletal model with backpack attachments in OpenSim 4.3. Inverse kinematics and ground reaction forces drove simulations of calibrated models of each participant and backpack condition. We quantified 3-dimensional lumbar joint contact forces. Compressive force impulse over right strides was evaluated for both L1L2 and L4L5 joints. ANOVA (α = 0.05) was used to test for main effects of backpack, slope, and the backpack-by-slope interaction. Pairwise comparisons using Tukey's HSD were performed when indicated by main effects. **Results:** A significant backpack-by-slope interaction was found for L4L5 ($p = 0.049$) and L1L2 ($p = 0.031$) compressive impulse. L1L2 pairwise results are presented here. In NoPack, L1L2 compressive impulse was 0.70 and 0.57 bodyweight-seconds greater during Up ($p < 0.001$) compared with Down and Level, respectively. In HipBelt, L1L2 compressive impulse was 0.50 bodyweight-seconds greater during Level compared with Down ($p < 0.001$) and was 0.33 bodyweight-seconds greater during Up compared with Level ($p = 0.009$). In Shoulder, L1L2 compressive impulse was 0.62 and 0.37 bodyweight-seconds greater during Up compared with Down ($p < 0.001$) and Level ($p = 0.002$), respectively. On Down, L1L2 compressive impulse was 0.50 and 0.29 bodyweight-seconds greater in Shoulder than in NoPack ($p < 0.001$) and HipBelt ($p = 0.032$), respectively. On Level, L1L2 compressive impulse was 0.58 and 0.62 bodyweight-seconds greater in HipBelt ($p < 0.001$) and Shoulder ($p < 0.001$) than in NoPack, respectively. On Up, L1L2 compressive impulse was 0.34 and 0.42 bodyweight-seconds greater in HipBelt ($p = 0.006$) and Shoulder ($p < 0.001$) than in NoPack, respectively. **Conclusions:** Carrying heavy backpacks causes high lumbar spine compressive forces, and the influence of a hip belt attachment depends on walking slope. **Military Impact:** Proper use of a hip belt to support backpack weight can reduce lumbar loading, especially when walking downhill. However, backpack design can be improved for level and uphill walking.

08:45 – 09:00: Effects of stature and load carriage on the running biomechanics of healthy men

Jaques Reifman [1], Junfei Tong [1], Adhitya V Subramani [1], Vivek Kote [1], Michael Baggaley [2],

[1]United States Army Medical Research and Development Command, USA
[2]University of Calgary, Canada; W Brent Edwards, University of Calgary, Canada

Purpose: Overuse musculoskeletal injuries, often precipitated by walking or running with heavy loads, are the leading cause of lost duty days or discharge during basic combat training (BCT) in the U.S. military. The present study investigates the impact of stature and load carriage on the running biomechanics of men during BCT. **Methods:** We collected computed tomography images and motion-capture data for 21 young, healthy men of short, medium, and tall stature (n = 7 in each group) running on a treadmill at 3.0 $m{\cdot}s^{-1}$ with no load, 11.3 kg load, or 22.7 kg load. We then developed individualised musculoskeletal finite-element models to determine the running biomechanics for each participant under each condition and used a probabilistic model to estimate the risk of tibial stress fracture during a simulated 10-week BCT regimen. **Results:** Under all load conditions, we found that the running biomechanics were not significantly different among the three stature groups. However, compared with no load, a 22.7 kg load significantly increased the stance duration by 15%, the peak joint reaction forces at the hip, knee, and ankle by 12 to 16%, the peak joint moments by up to 23%, and the tibial strain by 11%. In addition, load carriage increased the tibial stress-fracture risk by 100%. While the differences in stress-fracture risk among the three stature groups were not statistically significant, we observed a trend of increasing risk with taller statures. We obtained similar results, albeit with smaller statistically significant differences, when we compared the no load and the 11.3 kg load conditions. **Conclusions:** Load carriage, but not stature, significantly affected the running biomechanics of healthy men. We expect that the quantitative analysis reported here may help guide the development of individualised training strategies to decrease the incidence of stress fracture during BCT. **Military Impact:** As the Army's new training and testing doctrine shifts from a "one-size-fits-all" to a personalised approach, we believe that the ability to perform individualised analysis such as the one described in this study will support this doctrine and help enhance peak performance in U.S. soldiers.

09:00 – 09:15: Effects of stature and stride length on the running biomechanics of healthy women

Jaques Reifman [1], Aravind Sundaramurthy [1], Junfei Tong [1], Adhitya V Subramani [1], Vivek Kote [1], Michael Baggaley [2], Anup Pant [1], W Brent Edwards [2]

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Purpose: Non-combat musculoskeletal injuries affect force readiness and account for up to 60% of Service members' lost duty days in the U.S. Army. While several studies have shown that reducing stride length positively affects running biomechanics and has the potential to reduce

the incidence of musculoskeletal injury, we do not know whether stride length reduction affects individuals of varying stature differently. **Methods**: We investigated the effects of reducing the running stride length on lower extremity joint mechanics, tibial strain, and tibial stress fracture risk in young, healthy women of different statures. Using individualised musculoskeletal and finite-element models of women of short (n = 6; 1.48-1.60 m), medium (n = 7; 1.60-1.66 m), and tall (n = 7; 1.66-1.78 m) statures, we computed the joint mechanics and tibial strains for each participant as they ran on a treadmill at 3.0 m·s-1 with their preferred stride length and with a stride length reduced by 10%, using the beats of a metronome as a reference. Using a probabilistic risk-prediction model, we also estimated the stress fracture risk for a running regimen representative of a 10-week U.S. Army basic combat training (BCT). **Results:** When study participants reduced their stride length, we found that the running biomechanics were not significantly different among the stature groups. Compared to the preferred stride length, averaged over all participants, a 10% reduction in stride length significantly decreased hip ($p = 0.002$) and knee ($p < 0.001$) flexion angles during the stance phase. In addition, we observed significant decreases in peak hip adduction ($p = 0.013$), hip internal rotation ($p = 0.004$), knee extension ($p = 0.012$), and ankle plantar flexion ($p = 0.026$) moments, as well as hip, knee, and ankle joint reaction forces ($p < 0.001$) and tibial strain ($p < 0.001$). Finally, for the simulated BCT regiment, reducing the stride length decreased the stress fracture risk by up to 96%. **Conclusions:** Our results show that reducing the stride length positively altered the running biomechanics of women, decreasing tibial strain and stress fracture risk, regardless of stature. We also observed large between subject variability, which supports the development of individualised training strategies to decrease the incidence of stress fracture during BCT. **Military Impact:** Our ability to examine individualised running biomechanics will help quantify tibial stress fracture risk during military training, particularly as the U.S. Army shifts to a personalized training doctrine.

09:15 – 09:30: Speed and load, but not grade, reduce shock attenuation during a simulated ruck

AuraLea C Fain [1], Ayden McCarthy [1], Benjamin Hindle [2], Jordan Andersen [1], Bradley C Nindl [3], Jodie Wills [1], Joel Fuller [1], Tim Doyle [1]

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Purpose: This study explores feasibility of wearable sensors to estimate mechanical stress during loaded walking or rucking. This may help to provide information necessary manage biomechanical load to reduce injury risk and maximise performance. **Methods:** Nineteen participants (9 men, 10 women; 1.70 ± 0.08 m, 71.3 ± 15.4 kg, 26.3 ± 6.7 y) were self-reportedly free of injury, recreationally active, and able to don 23 kg. University ethical approval was attained, and all participants provided written informed consent. Randomisation determined gait condition (unloaded and loaded [23 kg]), while the order of grade (flat, uphill [+6%], and downhill [−6%]) and speed (4.25 and 4.75 m·s-1) were fixed. Tri-axial accelerations (±16 g, 1125 Hz) from Blue Trident inertial measurement units (IMUs) (iMeasureU, Vicon Ltd., Oxford, UK) were placed on the foot and pelvis and analysed using custom MatLab (R2021b) script. Three-dimensional accelerations were filtered using a 4th order Butterworth Filter (75 Hz) and a resultant acceleration profile was calculated. The last ten strides of each trial were used to calculate mean peak resultant acceleration and the time integral of the root mean square (RMS) resultant acceleration at the foot and pelvis. The difference between foot and pelvis locations for peak and integral values were used to assess attenuation. A four-way repeated measures ANOVA (Jamovi, v.2.3.21) was used to determine the effects of factors (load, speed, grade, and sex) on acceleration variables. Where necessary, Bonferroni correction was used for post-hoc pairwise comparisons of grade. Alpha level was set a priori at $p < 0.05$. **Results:** Peak accelerations were greater in downhill compared with flat at the foot and pelvis ($p < 0.01$), and greater flat compared with uphill at the pelvis ($p = 0.03$). However, acceleration attenuation and integral variables were not influenced by grade ($p > 0.05$). Resultant peak accelerations at the foot and pelvis were higher in running compared with walking ($p < 0.01$). The integral signal was higher in running compared with walking at the foot and pelvis ($p < 0.01$) and running significantly decreased integral attenuation ($p < 0.01$). Peak resultant accelerations at the pelvis were higher in unloaded compared with loaded ($p < 0.01$) but load significantly decreased the integral attenuation ($p < 0.01$). **Conclusions:** This study identified variables that may indicate increased mechanical load due to operational-specific demands associated with ruck tasks. Specifically, load reduces the ability to attenuate mechanical stress up the kinetic chain. **Military Impact:** Military practitioners may glean information about mechanical stress from IMUs worn during operational tasks to monitor biomechanical loads, which may supply knowledge to decrease injuries and enhance performance.

09:30 – 09:45: The effect of speed and load on non-linear measures of stride time

Patrick Slattery [1], Eduardo Cofré Lizama [1], Jon Wheat [2], Paul Gastin [1], Ben Dascombe [3], Kane Middleton [1]

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[2]Sheffield Hallam University, UK
[3]University of Newcastle, Australia

Purpose: Load carriage is a fundamental military duty that has been shown to contribute to the high incidence of musculoskeletal injury in soldiers. Non-linear measures of stride time can assist in understanding the impact of load carriage on gait regularity and statistical persistence. This study investigated the effect of speed and load on non-linear measures of stride time during load carriage. **Method:** Eighteen Australian Army soldiers (6 women, 12 men; height 1.77 ± 0.09 m, body mass 80 ± 16 kg, age 25 ± 5 y) completed a maximum of twelve 12-min walking trials on a motorised treadmill. Trials were performed at four speeds (self-selected [5.0 ± 0.2 $km \cdot h^{-1}$], 3.5 $km \cdot h^{-1}$, 5.5 km·h-1, 6.5 $km \cdot h^{-1}$) carrying three loads (0 kg, 23 kg, 35 kg) distributed in a vest and backpack whilst holding a replica rifle. Non-linear measures of stride time included detrended fluctuation analysis alpha (DFA) and sample entropy (SE). Linear mixed models were used to assess the effect of speed and load on each measure ($\alpha = 0.05$). Paired-sample t-tests were performed where significant main effects were found. **Results:** There were no interactions between speed and load for either variable ($p > 0.05$). There was a significant main effect of speed and load on SE ($p < 0.001$) but not DFA ($p = 0.758$ and 0.493, respectively). SE decreased with increasing speed across all conditions (3.5 $km \cdot h^{-1}$: 2.23 ± 0.17, self-selected: 1.68 ± 0.19, 5.5 $km \cdot h^{-1}$: 1.60 ± 0.15, 6.5 $km \cdot h^{-1}$: 1.48 ± 0.15; $p \leq 0.001$). SE increased with increasing load across all conditions (0 kg: 1.61 ± 0.27, 23 kg: 1.70 ± 0.30, 35 kg: 1.76 ± 0.26, $p < 0.05$). **Conclusions:** Faster marching speeds may reduce the degrees of freedom available to complete the goal of staying on the treadmill, resulting in soldiers increasing stride-time regularity. If transferable to overground marching, this could indicate that soldiers are loading similar structures of the lower body, potentially increasing their risk of overuse injury. Increasing load appears to elicit a decrease in regularity, suggesting that soldiers are not, or failing to, regulate their stride, potentially increasing the risk of task failure or acute injury. The consistency of the DFA alpha across speeds and loads suggests that soldiers maintain their persistence. **Military Impact:** Non-linear measures of stride time, particularly SE, could be a novel measure to assess the impact of load carriage and may assist in understanding lower-limb musculoskeletal injury risk.

09:45 – 10:00: The effect of biological sex and external load on lower extremity coupling variability of military personnel

Brooke Hoolihan [1], Jon Wheat [2], Ben Dascombe [1], Danielle Vickery-Howe [3], Kane Middleton [3]

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[2]Sheffield Hallam University, UK
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Purpose: Load-carriage-related lower-extremity overuse injuries frequently occur in military personnel, particularly within female soldiers when compared with male soldiers. Lower-extremity injuries have also previously been related to changes in coupling variability. Therefore, the risk of such injuries may increase with changes in coupling variability due to biological sex or the application of external loads. This study aimed to quantify changes in lower extremity coupling variability during incremental load carriage walking in male and female military personnel. **Methods:** Fourteen Australian Army soldiers (7 males, 7 females; mean ± SD, body mass = 76.9 ± 15.6 kg, age = 26.5 ± 5.5 y, height = 1.73 ± 0.09 m) completed three 12-minute walking trials at 5.5 $km \cdot h^{-1}$ on an AMTI dual-belt treadmill wearing external body-borne load (0 kg, 23 kg, 35 kg). A Vicon system captured segment motion of the thigh, shank, and foot. Continuous relative phase standard deviation (CRPv) was calculated to quantify the variability of the Thigh-Shank and Shank-Foot couplings. Statistical parametric mapping repeated measures ANOVAs and post-hoc paired t-tests compared CRPv between external loads and biological sex. **Results:** There was no main effect for biological sex in the coupling variability of any segment ($p > 0.05$). There was a main effect of load for the Thigh-Shank ($p < 0.026$) and Shank-Foot ($p < 0.011$) couplings. Thigh-Shank coupling variability was greater for the 35 kg condition than the 0 kg condition ($p = 0.05$), and the 23 kg condition than the 35 kg ($p = 0.022$) condition. Shank-Foot coupling variability was greater for the 23 kg and 35 kg conditions than the 0 kg condition ($p < 0.001$ and $p < 0.049$, respectively). **Conclusions:** The results demonstrate that regardless of biological sex, coupling variability increases with the application of external

load, agreeing with previous research. This research proposed that applying external load acts as a perturbation that requires adaptation to ensure task completion. The increased coupling variability might provide flexibility and adaptability that helps to avoid task failure, redistribute forces to reduce cumulative overuse injury risk, and/or help maintain other key aspects of gait control (i.e., centre-of-mass displacement and energetic cost). **Military Impact:** Coupling variability may be a novel and promising technique to assess injury risk and task demands in military personnel. Understanding the relationship between coupling variability and injury risk may enable the development of monitoring programs to identify military personnel at risk of injury and enhance personnel availability.

Oral Communication 15: Psychological Resilience and Performance

Thursday 14th September, 08:30 to 10:00

Room 1

Chair: *Karl Friedl, US Army Research Institute of Environmental Medicine, USA*

08:30 – 08:45: A six-week brain endurance training (BET) program improves endurance and cognitive performance, and enhances resilience to fatigue in elite athletes

Walter Staiano [1], Samuele Marcora [2], Marco Romagnoli [1], Ulrich Kirk [3], Christopher Ring [4]

[1]University of Valencia, Spain
[2]University of Bologna, Italy
[3]University of Odense, Denmark
[4]University of Birmingham, UK

Purpose: It has repeatedly been demonstrated that mental fatigue impairs endurance performance, affects cognitive capacity, and alters perception of effort. We aim to evaluate the effects of an innovative cognitive training, namely, Brain Endurance Training (BET), on endurance and cognitive performance in fresh and fatigued states in an elite cyclist population. **Methods:** In two independent randomised controlled pretest-posttest training studies, elite cyclists trained five times per week for six weeks and completed either cognitive response inhibition tasks (Post-BET group) or listened to neutral sounds (control group) after each training session. In Study-1, 26 male cyclists (age 29 ± 5 years, height 177 ± 6 cm, body mass 70 ± 9 kg, Peak Power Output [PPO] 348 ± 55 W, VO_{2peak} 64 ± 4 $ml \cdot kg^{-1} \cdot min^{-1}$, > 3 training sessions/week, > 250 km per week, > 3 years cycling experience) performed a Time To Exhaustion (TTE) test at 80% PPO, followed by a 30-min Stroop task, and a TTE test at 65% PPO. In Study-2, 24 male cyclists (age 25 ± 4 years, height 179 ± 5 cm, body mass 69 ± 7 kg, PPO 401 ± 44 W, VO_2peak 70 ± 5 $ml \cdot kg^{-1} \cdot min^{-1}$, > 4 training sessions/week, > 400 km/ week, > 5 years cycling experience) performed a 5-min Time Trial (TT), followed by a 30-min Stroop task, 60min submaximal incremental test, and a 20-min TT. Heart rate, lactate, RPE, Stroop reaction time, and accuracy were also measured. Statistical analysis was conducted using series of mixed ANOVAs. **Results:** During study 1, Post-BET improved TTE at 80% ($p = 0.032$) and 65% PPO ($p = 0.011$) significantly more than the control with lower RPE (all $p < 0.043$). In study 2, 5-min TT performance did not differ between groups. During the 60-min submaximal incremental test, RPE was lower in the Post-BET group compared with the control group ($p = 0.034$), and 20-min TT performance improved significantly more in the Post-BET group than in the control group (all $p < 0.031$). No group differences were found in physiological measures. In both studies, Stroop reaction times improved significantly more (all $p < 0.033$), felt less mentally demanding (all $p < 0.031$), and less effortful (all $p < 0.034$) in the Post-BET group than in the control group. **Conclusions:** These findings suggest Post-BET may be used to improve the endurance performance of elite cyclists in both fresh and fatigued states, confirming its efficacy in boosting endurance performance as well as resilience toward mental and physical fatigue. Importantly, Post-BET reduced RPE during endurance and cognitive performance, suggesting that Post-BET improves general performance by making a task feel easier to accomplish. **Military Impact:** Research has confirmed that both physical and cognitive fatigue can reduce human capability to optimally perform among a variety of military populations. Therefore, BET may be a safe, feasible, and effective countermeasure strategy to improve human capability, and reduce the likelihood of personnel making errors, losing focus, and taking poor decisions, particularly in fatigued states.

08:45 – 09:00: Using accelerometry and heart rate data for non-metabolic stress modelling and real-time monitoring of soldiers' stress in dynamic military virtual reality scenario's

Olaf Binsch [1], Lotte Linssen [1], Jan U van Baardewijk [1], Charelle Bottenheft [1], Annemarie Landman [1]

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Purpose: Real-time physiological stress monitoring would be a relevant addition to virtual reality (VR) training for high-risk professions, such as the military. VR is highly suitable for the implementation of such monitoring due to the controlled environment and the already available wearables. However, physiological stress measurements suffer from distortion due to physical activity. **Methods:** The initial trial determined whether accelerometry via single accelerometer sensor at the hip of the soldier could be used to correct non-invasively measured heart rate (HR) for physical activity in 23 soldiers who performed three close-quarters battle (CQB) VR scenarios. These scenarios were dynamic, in that soldiers moved around in the VR environment and conducted their standard CQB procedures induced by VR simulation. In a second experiment, we placed additional accelerometer sensors on the feet, shoulder, and hands of the participant whilst additional standard movements were added as reference for normal vs typical CQB movement behaviour. **Results:** In contrast to uncorrected HR, and HR corrected by subtracting baseline HR measured when walking, the accelerometry corrected HR was able to significantly predict the participants' self-reported stress in the scenarios ($p = 0.047$, $R^2 = 0.11$ in the first experiment). Whereas uncorrected HR significantly predicted self-reported physical demand ($p = 0.028$, $R^2 = 0.09$), the accelerometry-corrected HR did not. All HR measures significantly predicted self-reported mental effort, which was strongest for uncorrected HR ($p < 0.001$, $R^2 = 0.42$). The second experiment showed that placing extra accelerometer sensors in combination with adding some extra movements improved our non-metabolic stress model. **Conclusions:** These findings—in combination with the methods' low sensitivity to motion artifacts and non-invasiveness—are very promising for its use to monitor stress in real-time during dynamic VR training scenarios. **Military Impact:** Real-time physiological stress monitoring using VR could have a significant impact on the military, particularly in terms of improving the performance and well-being of soldiers. This CQB VR scenario can be used or further improved to simulate high-stress combat scenarios, allowing soldiers to practice their skills in a safe environment. By monitoring physiological stress responses during training, commanders, instructors and / or coaches can identify areas where soldiers may need additional support or training. In addition, this VR CQB test platform seems sensitive enough to also measure the effects of applicable Human Augmentation technologies.

09:00 – 09:15: Sleep and work demands contribute to daytime impairment and depressive symptoms in a shipboard environment

Alice LaGoy [1], Jason Jameson [1], Peter Roma [1], Andrew Kubala [1], Luis Rosado [1], Sean Deering [1], Joseph Cuellar [1], Dale Russell [2], Rachel Markwald [1]

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[2]Naval Surface Force, USA

Purpose: Military personnel regularly experience poor sleep (e.g., short duration, low quality), which can lead to chronic disturbances in performance and well-being. It is important to examine these prolonged effects in combination with the potential contribution of work demands. This study explored the effect of sleep on daytime dysfunction in two crews of sailors exposed to different work demands over a 9-month in-port period. **Methods:** Sailors ($n = 69$, 33 ± 7 y, 22% female) wore a commercial wearable sleep-tracking device continuously (Oura Ring, Gen2) and completed surveys at five time points (September 2021 – May 2022). Sailors slept at home and experienced high work demands when they were on-hull (working on the ship), and lower work demands when they were off-hull (working off the ship). Sleep tracker outcomes from the week prior to survey completion included: total sleep time (TST; sleep duration), and sleep efficiency (SE; proportion of time in bed spent asleep). Surveys assessed sleep quality (Pittsburgh Sleep Quality Index; PSQI), depressive symptoms (Patient Health Questionnaire-8; PHQ-8), and daytime impairment due to fatigue (PROMIS Sleep-related Impairment scale; SRI). Linear mixed models were used to explore the effects of sleep on depressive symptoms and daytime impairment. Timepoint and work demands (on-hull / off-hull periods) were also included as fixed effects, while participant was included as a random effect. All models controlled for age and sex. **Results:** Sailors reported mild depressive symptoms (PHQ-8: 5.3 ± 5.4) and average levels of daytime impairment according to established normative values (SRI: 51.7 ± 9.8). Higher PSQI scores (worse sleep quality) predicted higher PHQ-8 scores ($\beta = 0.69$, $p < 0.001$) and higher SRI scores ($\beta = 1.25$, $p < 0.001$). A statistically significant work demand × TST effect on SRI was found ($\beta = -4.29$, $p = 0.02$): during on-hull periods higher TST predicted lower SRI ($\beta = -5.10$, $p < 0.001$), but this relationship was not observed when off-hull. For this limited sample, no other sleep outcomes nor timepoint were reliably related to PHQ-8 or SRI. **Conclusions:** Worse self-reported sleep quality predicted more depressive symptoms and daytime impairment. Further, obtaining more sleep during high work demand periods was associated with lower daytime impairment. **Military Impact:** Military effectiveness relies on the mental health and readiness of personnel, both of which are affected by poor sleep. Prioritising sleep when work demands are high may be essential to maintaining effective operational readiness and psychological resilience.

09:15 – 09:30: The relationship of psychological inflexibility and the experience of pain in active-duty US Army soldiers

Jason L Judkins [1], Bradley M Ritland [1], Julianna M Jayne [1]

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Purpose: Active-duty soldiers experience mental and physical challenges while functioning in high-risk environments, increasing the risk for pain. Prevalence estimates of chronic pain in active-duty soldiers range from 35% to 59% (35% to 55% with moderate levels of pain intensity), compared with 20% in the U.S. general population. Higher rates of chronic pain within the military may stem from acute injuries going untreated due to the mentality of pushing through the pain to maintain readiness and to avoid being placed on duty limitations that may impact career progression or affect their ability to remain on active duty. Soldiers may rely on negative coping strategies, such as psychological inflexibility, that may contribute to experiencing decreased psychological health; psychological inflexibility has been shown to have a negative impact on the experience of pain in other populations. The commonality of pain coupled with the potential negative impact of psychological inflexibility on pain experience makes it imperative to explore this relationship. The purpose of this study is to address this gap and examine the relationship. **Methods:** A secondary data analysis was undertaken from a longitudinal observational study of soldiers within the 2nd Brigade Support Battalion (BSB), 2nd Infantry Division or the 626 BSB, 101st Airborne Division between fall 2020 and spring 2021. Participants were given the Acceptance and Action Questionnaire-II (AAQ-II) and a questionnaire that included a numerical pain rating scale (0-10). A linear regression and ordinal logistic analysis were conducted to examine associations between psychological inflexibility and pain intensity and pain intensity groups. The model controlled for age, sex, level of education, and tobacco use. **Results:** A total of 819 participants (age 27.0 ± 6.5 y, 81.2% male, 38.6% high school degree, and 76.3% non-tobacco users) completed the study. Average pain scores were 2.2 ± 2.5 and the average score on the AAQ-II was 17.6 ± 10.1. Pain and psychological inflexibility were significantly associated ($F = 13.8$, $p < 0.001$) such that those who reported higher levels of psychological inflexibility had significantly greater levels of pain intensity. Psychological inflexibility also significantly predicted levels of pain intensity ($ß = 0.04$, $SE = 0.01$, $OR = 1.04$, $p < 0.001$), with each point increase in psychological inflexibility was associated with about 4.0% increase in pain intensity. **Conclusions:** This study found that higher levels of self-reported psychological inflexibility were associated with worse levels of pain intensity in active-duty soldiers. **Military Impact:** It is important to consider how soldier's coping strategies may be negatively related to pain intensity, which could negatively impact military retention and job performance.

09:30 – 09:45: Sex differences in mood states and cortisol response to hand-to-hand combat training in U.S. Military Academy Cadets

Meaghan E Beckner [1], Jesse A Stein [1], Mary R Lee [1], Joseph J Knapik [1], Emily K Farina [1], Drew Van Dam [2], Nicholas D Barringer [2], Matthew Larsen [2], Harris R Lieberman [1]

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Purpose: Hand-to-hand combat training is designed to teach Soldiers close quarters combat techniques, how to cope with stress, and develop self-confidence. The physiological response to psychosocial stress is known to differ by sex and previous reports suggest men are more stress resistant than women. Whether the stress of hand-to-hand combat training impacts men and women differently is unknown. This study investigated sex differences in mood state and hormone response to hand-to-hand combat training. **Methods:** U.S. Military Academy Cadets (men = 144, women = 37) enrolled in a 2-month Combat Applications Course at West Point completed the Profile of Mood States and Competitive State Anxiety Inventory-2 and provided salivary samples at baseline prior to the course, and immediately prior to their midterm and final combat matches. Cadets were instructed to respond to surveys according to their feelings in the moment. Concentrations of cortisol and testosterone, and oestradiol in women only, were measured in salivary samples. Men and women were compared over time with linear mixed effects models. **Results:** Independent of sex, confusion, tension, anger, cognitive anxiety, somatic anxiety, and self-confidence increased throughout the course whereas friendliness decreased (all $p < 0.05$). Compared with women, men reported higher ratings of friendliness (mean difference [95% CI], 2.0 [0.7,3.2], $p = 0.003$) and vigour (2.0 [0.4,3.7], $p = 0.014$). Prior to the final match, women displayed higher tension than men (20.5 ± 9.3 vs 16.0 ± 8.6, $p < 0.001$). After controlling for previous combative experience, ratings of tension did not differ by sex but remained elevated prior to midterm and final compared to baseline. Cortisol concentrations were elevated from baseline to midterm (0.1 [0.0,0.1] $\mu g \cdot dL^{-1}$, $p = 0.003$) and final (0.2 [0.1, 0.2] $\mu g \cdot dL^{-1}$, $p < 0.001$). At the final match, cortisol concentrations were higher in women (0.6 ± 0.3 $\mu g \cdot dL^{-1}$) than men (0.4 ± 0.3 $\mu g \cdot dL^{-1}$, $p = 0.002$). No significant changes in testosterone or oestradiol were observed throughout the course. **Conclusions:** Hand-to-hand combat training elicited negative mood states and increased cortisol in both men and women, though women displayed greater tension at the final match likely due to lack of previous experience. Other factors beyond the combat applications course, such as academic and life stress, could not be controlled and may have contributed to the stress response. Despite increased anxiety, self-confidence increased from baseline suggesting that the skills learned may have helped Cadets feel better prepared for hand-to-hand combat. **Military Impact:** Close-quarters combat training elicits significant psychological and physiological stress in both men and women and increases in self-confidence. Authors' views not official U.S. Army or DoD policy.

Oral Communication 16: Environmental Stressors, Exposures, and Injuries

Thursday 14th September, 08:30 to 10:00

Room 3

Chair: *Hilde K Teien, Norwegian Defence Force, Norway*

08:30 – 08:45: British military personnel with non-freezing cold injury have increased pain and reduced quality of life due to delayed and unsuitable rehabilitation

Lynn Kelly [1], Ellen Slungaard [1]

[1]*Defence Medical Rehabilitation Centre Stanford Hall, UK*

Purpose: Non-freezing cold injury (NFCI) is a vaso-neuropathy occurring as a result of exposure to cold/wet conditions. Affecting predominantly the hands and feet, sufferers experience pain, numbness, paraesthesia, swelling and hot/cold sensitivity. **Methods:** A retrospective analysis of medical records was conducted of all patients with NFCI attending Defence Medical Rehabilitation Centre (DMRC) Stanford Hall between Jan 2019 and Dec 2022. Search parameters included age, military branch, biological sex, current rank, ethnicity, time from reporting/diagnosis to referral for rehabilitation, body parts affected, other MSK and mental health conditions developed since diagnosis, current employment, pain scores, and other conditions that may account for a peripheral neuropathy. **Results:** The outstanding feature of this study is the delay in time from diagnosis to rehabilitation; mean 539 days. A total of 146 records were reviewed and 25 were included for analysis. All subjects were male, in the Army, of low rank (Pte to Cpl), with a mean age 34.8 y. Access to rehabilitation ranged from 196 – 1175 days from first reporting. Musculoskeletal conditions developed in 42% of patients and 92% developed a mental health condition. Pain intensity and interference, i.e., the extent to which pain impacts on activities of daily living, is reported as moderate to severe and 90% had neuropathic symptoms affecting their feet which can lead to changes in gait, balance, proprioception and all candidates reported that pain had an impact on mobility. NFCI resulted in all of the patients being discharged from active military service. **Conclusions:** One potential reason could be the delay in accessing rehabilitation is the lack of formal diagnosis due to the lack of a reliable diagnostic test and lack of awareness of the benefits of rehabilitation. Severe pain with neuropathic symptoms is a key feature of NFCI, as seen with this group. The impact of this can be catastrophic in terms physical function and of quality of life. Further detriment to quality of life occurs because of the career and work restrictions that can be in place for a minimum of 4 years. This can lead to reduced income, loss of promotion, feelings of isolation, shame, stigma, and loss of meaningful employment. Undoubtedly this contributes to the poor mental health seen in majority of this cohort. Given the biopsychosocial nature of NFCI and the impact in terms of high levels of pain and reduced quality of life, early rehabilitation is essential, however, to date this is the first example of considering rehabilitation in the management of NFCI. **Military Impact:** This study concludes that current rehabilitation provision to British soldiers with NFCI is inadequate in preventing a severe biopsychosocial impact and reduction in their long-term quality of life.

08:45 – 09:00: Potential impact of a ventilated vest on perception, physiology, and cognition of Soldiers in controlled and uncontrolled warm environments

Milène Catoire [1], Lotte Linssen [1], Lisa Klous [1], Laura Ahsmann [1], Jikke Reinten [1], Sam Ballak [1], Barbara Vos [2], Erlynne Bakkers [2], Boris Kingma [1]

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Purpose: There is a clear need for cooling strategies for ensuring optimal operational performance in military context. Therefore, an active ventilated vest specific for the dismounted Soldier was developed and evaluated during several experiments in controlled and uncontrolled warm environments. The objective of these experiments was to assess the effectiveness and acceptance of this ventilated vest. **Methods:** The ventilated vest was evaluated in a four-phase experimental set up consisting of a thermal mannequin test, a controlled test in a climatic chamber (32°C, 33% relative humidity), a controlled field test (Netherlands), and an uncontrolled field test (Curacao, Dutch Caribbean). A wide set of outcome measures were assessed during one or more of the performed tests, such as evaporative resistance, core temperature, heart rate, cognitive performance (sustained attention), user acceptance and usability. Difference between conditions were tested using a paired sample t-test ($p < 0.05$). **Results:** The thermal mannequin test showed a significant reduction in thermal insulation (−50%) and evaporative resistance (−79%) for the ventilated vest in combination with the ballistic vest compared to ballistic vest alone (control). The controlled climatic chamber test showed a significantly lower core body temperature for the ventilated vest condition compared to control (37.71 ± 0.36 °C vs 37.95 ± 0.35 °C; $p = 0.008$; $n = 8$) and faster HR recovery during rest period for the ventilated vest condition compared to control (Δ9 ± 12 $b \cdot min^{-1}$; $p = 0.008$). There was a higher reaction time in the ventilated vest condition (379 + 51 s) compared to control (334 + 24 s, $p = 0.013$). The number of errors was lower whilst wearing the ventilated vest (7 + 5 errors) than control (11 + 4 errors, $p = 0.033$). The field tests (controlled and uncontrolled) showed a sufficient to good user acceptance and usability for the ventilated vest, while simultaneously pinpointing out several weaknesses such as local discomfort and issues with doffing. **Conclusions:** The four-phase experimental set up showed that the ventilated vest decreased the thermal load, reduced the physiological load, and impacted cognitive performance. These positive objective outcomes were accompanied by promising results on usability of the ventilated vest in operational settings, although further development is needed to further increase usability and comfort. **Military Impact:** This study shows that a ventilated vest could be an effective method to mitigate heat stress and optimize operational performance for Soldiers.

09:00 – 09:15: Physiological and subjective responses during work in encapsulated suits under day and night conditions in the tropics

Wee Hon Ang [1], Ya Shi Teo [1], Jason Lee [1]

[1]National University of Singapore, Singapore

Purpose: This study evaluated the safety of chemical, biological, radiological, and explosive (CBRE) troopers working in encapsulated suits by profiling their thermoregulatory responses and fluid balance during day and night deployments in the tropics. **Methods:** Sixty-two male military personnel participated in both day (outdoor Wet Bulb Globe Temperature [WBGT]: 31.0 ± 0.3°C) and night (outdoor WBGT: 25.7 ± 0.2°C) deployment trials wearing protective suits.

Each trial was conducted over two 1 h work-rest cycles (Day: 35 min work / 25 min rest; Night: 45 min work / 15 min rest). Troopers were either responsible for decontamination (indoor) or screening, triaging, and transportation of casualties using stretchers (outdoor). Results: Resting skin temperature (Tsk) and heart rate (HR) were similar between conditions, but higher resting core temperature (Tc) was observed in the night (37.8 ± 0.2°) than day (37.4 ± 0.2°; $p < 0.001$). No difference in peak and mean Tc were observed between the day and night trials. Mean HR was similar between conditions, but peak HR was higher in the night (161 ± 25 $b \cdot min^{-1}$) than day (152 ± 22 $b \cdot min^{-1}$; $p < 0.05$). Peak and mean Tsk, changes in ratings of perceived exertion and thermal sensation, baseline urine osmolality, sweat loss, and fluid intake were higher in the day than night (all $p < 0.001$). Conclusions: We reported the physiological and subjective responses of CBRE troopers during day and night deployments. Although there was higher environmental heat load in the day than night, the higher resting Tc and longer work period in the night than day (due to circadian rhythm) resulted in similar peak and mean Tc in both conditions. Military Impact: In the tropics, the advantages of daytime (lower resting Tc and drier air) compared to night-time operations is diminished due to the encapsulated suits donned by CBRE operators.

09:15 – 09:30: Heat stress in armoured vehicles: challenges and solutions

Maria Richter [1], Ulrich Rohde [1], Leonard Stratmann [1], Karl J Glitz [1], Manuela Andrea Hoffmann [1]

[1]Bundeswehr Institute for Preventive Medicine, Germany

Purpose: Reports from Soldiers indicate that significant heat stress can occur in armoured vehicles despite air conditioning, especially in hot environments. It is further exacerbated by the high thermal insulation of military clothing and ballistic body armour. To gain more accurate knowledge, various armoured vehicles were exposed to desert and tropical climates in a climate chamber in accordance with NATO STANAG 4370 test protocols, and the resulting interior climate was measured. Inside air temperatures ranging from 31°C up to 57°C and wet bulb globe temperature values of up to 37°C were recorded. The objectives of this study were to determine (1) how heat stress inside vehicles affects the crewmembers, and (2) whether an airflow cooling vest can significantly mitigate that heat stress. **Methods:** We simulated a patrol in which Soldiers alternate between driving in a vehicle (Phase I: 1.5 h, Phase III and V: 0.5 h, sitting) and patrolling on foot (Phase II and IV: 0.5 h, march on a treadmill at 3 $km \cdot h^{-1}$). In the driving phases, Soldiers wore combat clothing, gloves, goggles, and ballistic protection vest (total weight: 26 kg); during the foot patrol phases, they added a helmet and rifle (total weight: 30 kg). Nine healthy, voluntary, experienced Soldiers (3 women, 6 men) underwent the protocol in “desert” (air temperature = 44°C, relative humidity = 20%) and “tropical” conditions air temperature = 38°C, relative humidity = 75%) in a climate chamber. Conditions correspond to the averaged measured climates in the vehicles. Each condition was run once with / without the cooling vest through which dry, conditioned air flows during the driving simulation. **Results:** During the test runs without cooling vest, core temperature of the participants increased by 1.5 ± 0.3°C on average under “desert” and by 2.0 ± 0.1°C under “tropical” conditions. In the “tropical” climate, all participants reached the safety threshold of a core temperature of 39°C and had to end the test run prematurely. The cooling vest significantly ($p < 0.001$) attenuated the increase in core temperature in both climates. In the cooling vest trials, the core temperature at the end of the trial was 0.7 ± 0.3°C lower than in the no cooling vest trials. **Conclusions:** Passive heat stress in vehicles substantially increases core body temperature, which reduces the capacity for heat tolerance during subsequent physical exertion. In addition, the passive heat stress prevents regeneration after re-entering the vehicles. We showed that cooling the crew with dry air during drives is a promising way to maintain their health and performance. **Military Impact:** The results will help to minimise the risk of heat illness and consequently, the risk of failure of military operations.

09:30 – 09:45: Susceptibility to acute mountain sickness negatively impacts sleep and nocturnal oxygenation at 3600 m but active ascent does not result in greater decrements

Steven Landspurg [1], Peter Figueiredo [1], Janet E Staab [1], Mark Buller [1], Reed Hoyt [1], J Philip Karl [1], Beth A Beidleman [1], Jon Femling [2], Jason Williams [2], Aaron Reilly [2], Trevor Mayschak [2]

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Purpose: Previous reports suggest that strenuous exertion during ascent to high altitude (HA) may be related to the development of Acute Mountain Sickness (AMS). Whether AMS-susceptibility differentially impacts sleep in individuals following active and passive ascent to 3600 m remains unknown. **Methods:** 78 healthy soldiers (mean ± SD; age = 26 ± 5 y) were tested at baseline residence (BLR), transported to Taos, New Mexico (2,845 m), then hiked (n = 39) or were driven (n = 39) to 3600 m, and stayed for four days. AMS-C was assessed using the Environmental Symptoms Questionnaire (ESQ-III) at HA twice on day 1, five times on days 2 and 3, and once on day 4. If AMS-C was ≥ 0.7 at any timepoint, individuals were categorised as AMS-susceptible (AMS+, n = 33) with others categorised as non-susceptible (AMS−, n = 45). Sleep was assessed via actigraphy each night (BLR, Han1, Han2, Han3) and used to calculate sleep efficiency (%), duration (min), onset latency (min), wakefulness after sleep onset (WASO, min) and awake index (events / hour). Pulse oximetry was measured continuously to assess mean nocturnal peripheral oxygen saturation ($nSpO_2$, %), mean nocturnal heart rate (nHR, $b \cdot min^{-1}$) and desaturation index (events / hour). Data are missing from two participants for sleep metrics (n = 76), four participants for pulse oximetry (n = 74), and eight for desaturation index (n = 70). **Results:** Sleep efficiency, onset latency, WASO, and awake index did not differ between AMS-susceptibility groups regardless of ascent conditions. The AMS+ vs AMS− group demonstrated less sleep duration at Han1 (388 ± 68 *vs* 415 ± 51 min, p = 0.007) and Han3 (383 ± 59 *vs* 421 ± 58 min, p = 0.05) only in the active ascent cohort. Nocturnal SpO_2 was lower in the AMS+ *vs* AMS− group at Han1 (79.3 ± 4.4 *vs* 82.5 ± 3.1 %, p = 0.040) and Han2 (80.4 ± 3.8 *vs* 84.1 ± 2.9 %, p = 0.007) in the active ascent cohort and lower in the AMS+ *vs* AMS− group at Han3 (81.3 ± 6.3 *vs* 84.2 ± 3.4 %, p = 0.030) in the passive ascent cohort. HR was not differentially impacted between AMS-susceptibility groups for either ascent cohort. Desaturation index (events/hour) was higher in AMS+ than AMS− on nights Han1 (42.5 ± 36.9 *vs* 22.2 ± 17.5, p = 0.026) and Han2 (34.0 ± 31.9 *vs* 17.2 ± 15.5, p = 0.046) in the active ascent cohort while AMS-susceptibility did not impact the desaturation index in the passive ascent cohort. **Conclusions:** Sleep quantity and nocturnal oxygen saturation were negatively impacted by AMS-susceptibility but active compared with passive ascent did not result in greater decrements. **Military Impact:** The presence of AMS can negatively impact sleep and oxygenation during overnight altitude operations, potentially interfering with mission success and safety. Authors' views not official U.S. Army or DoD policy.

Oral Communication 17: Physical Performance

Thursday 14th September, 08:30 to 10:00

Room 3

Chair: *Charlotte V Coombs, Army Health and Performance Research, UK*

08:30 – 08:45: The Pandolf load carriage equation systematically underpredicts the metabolic cost of load carriage in males and females

Jace Drain [1], Danielle Vickery-Howe [2], Anthea C Clarke [2], Ben Dascombe [3], Kane Middleton [2]

[1]Defence Science and Technology Group, Australia
[2]La Trobe University, Australia
[3]University of Newcastle, Australia

Purpose: Compare the validity of the Pandolf load carriage equation between males and females across three different external load conditions. **Methods:** Fifteen male (age: 22.3 ± 2.3 y, height: 1.79 ± 0.07 m, body mass: 74.2 ± 8.5 kg, predicted VO_2max: 48.7 ± 2.9 $mL·kg^{-1}·min^{1}$, mean ± SD) and 15 female (age: 25.1 ± 6.1 y, height: 1.65 ± 0.07 m, body mass: 61.5 ± 6.9 kg, predicted VO_2max: 44.1 ± 3.8 $mL·kg^{-1}·min^{-1}$) participants completed three load carriage trials comprised of incremental external loads (0, 20, and 40% body mass [BM]) at a self-selected walking speed on a treadmill for 10 min per load condition. The control condition (0% BM) was performed first, followed by the 20% BM (10 to 20 kg) and 40% BM (20 to 40 kg) trials with 10 min passive rest between trials. The torso-borne load was distributed equally between front and back. Oxygen consumption was measured with a portable gas analysis system (Oxycon Mobile, Jaeger). Three-way analysis of variance was used to assess sex × external load × measurement type (measured / predicted) interactions. Statistical significance was set at $p < 0.05$. Bland-Altman plots assessed agreement between measured and predicted metabolic rate. Analysis was performed in GraphPad Prism (v7.0). **Results:** There were no significant interactions between sex, load, and measurement type ($p = 0.997$). There was a significant main effect for measurement type ($p < 0.001$). The Pandolf equation demonstrated poor predictive precision, with a mean ± SD bias of 0.211 ± 0.102 $L·min^{-1}$ for males and 0.195 ± 0.101 $L·min^{1}$ for females. Furthermore, the Pandolf equation systematically underpredicted the metabolic rate of load carriage by 16-17% for males and 17-19% for females across all load conditions ($p < 0.05$). There was no difference in the prediction error (% error) between males and females (17.2 ± 6.6% vs 18.7 ± 8.5%, $p > 0.05$). The relative and absolute error rates are consistent with previously published work with male participants. **Conclusions:** These results extend previous findings, demonstrating that the Pandolf equation systematically underpredicts the metabolic rate of load carriage in both males and female, with a consistent error rate between sexes. **Military Impact:** Whilst it is suggested that the Pandolf equation should be used with caution, it can be applied equally across sexes when planning load carriage activities involving torso-borne loads of 10 to 40 kg and walking speeds between 3.5 and 5.8 km·h-1. Furthermore, the current results combined with recently published work demonstrate that a correction factor of ~15% may improve prediction accuracy.

08:45 – 09:00: Physiological responses across a 2-hour loaded march in male soldiers

Ben Dascombe [1], Danielle Vickery-Howe [2], Greg L Carstairs [3], Brooke Hoolihan [1], Jace Drain [3], Kane Middleton [2]

[1]*University of Newcastle, Australia*
[2]*La Trobe University, Australia*
[3]*Defence Science and Technology Group, Australia*

Purpose: The metabolic demands of loaded marching in soldiers have been shown to increase with duration, suggesting a loss of metabolic efficiency over time. However, the reported intensity for loaded marching (~50% VO_{2max}) is lower than that which corresponds to the development of a metabolic slow component. This slow component reflects an increased recruitment of the less-efficient Type II muscle fibres and can be observed through muscle oxygenation changes. This study aimed to quantify the physiological responses of soldiers during a 2 h loaded march in male soldiers. **Methods:** Eleven Australian Army male soldiers (n = 11, age 22 ± 3 y, height 1.81 ± 0.09 m, body mass 86.7 ± 11.7 kg) completed a 2 h loaded march at 5.5 $km{\cdot}h^{-1}$ across overground terrain (9 laps of a 1.2 km course with 12 m elevation), carrying 23 kg of external load while holding a replica F88 rifle. Throughout the march, soldiers wore a Metamax 3B to analyse expired gases and record heart rate. Muscle oxygenation measures (muscle oxygenation [SmO2]; total haemoglobin [tHb]) of the vastus lateralis and medial gastrocnemius were collected using mOxy monitors. All data were analysed across each lap and then a repeated measures analyses of variance were employed to identify any changes across laps. Paired-sample t-tests were performed where significant main effects of lap number were present, with $p < 0.05$ considered statistically significant. **Results:** There were no significant main effects for lap number for any physiological measures across the march. Oxygen consumption (mean ± SD) was 1.9 ± 0.2 $L{\cdot}min^{-1}$ (22.4 ± 2.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) throughout the entire march, remaining consistent between laps 1 to 9 (increase: 0.2 ± 0.3 L·min-1; 2.9 ± 3.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$). Mean heart rate was stable across the march (128 ± 13 $b{\cdot}min^{1}$; ~65% estimated HR_{max}), despite demonstrating some drift (11 ± 6 $b{\cdot}min^{-1}$). Muscle oxygenation for both the vastus lateralis (SmO2: 86.9 ± 4.8%; tHb: 12.28 ± 0.26) and gastrocnemius (SmO2: 62.3 ± 19.4%; tHb: 12.50 ± 0.46) remained stable between laps 1 to 9 (Thigh: 1.0 ± 2.4%; tHb: 0.06 ± 0.17; Calf: −1.75 ± 15.20%; tHb: −0.10 ± 0.35). **Conclusions:** This study quantified the physiological responses of male soldiers throughout a 2 h loaded march at 5.5 $km{\cdot}h^{-1}$. The data demonstrated that soldiers maintained a moderate intensity, resulting in no slow component development which suggests that there were no fatigue-related changes in muscle fibre recruitment. Future work is required to explore whether such a fatigue-related slow component develops during prolonged marches that evoke higher physiological intensities (e.g., above ventilatory threshold). **Military Impact:** Physiological responses remained consistent across a prolonged loaded field march, helping to inform training practices and identify mechanisms of fatigue that might affect task performance.

09:00 – 09:15: The physiological and biomechanical effects of weapon handling during load carriage

Danielle Vickery-Howe [1], Jace Drain [2], Ben Dascombe [3], Anthea C Clarke [1], Brooke Hoolihan [4], Kane Middleton [1]

[1]La Trobe University, Australia
[2]Defence Science and Technology Group, Australia
[3]Western Sydney University, Australia
[4]University of Newcastle, Australia

Purpose: Weapon handling during marching restricts arm swing and shifts a portion of load anteriorly. Despite weapon handling being essential during training and operations, few investigations have explored the effects of this task during load carriage. This study investigated the effects of weapon handling on physiological responses and walking gait during load carriage. **Methods:** Seventeen Australian Army Soldiers (12 men, 5 women; age = 25.4 ± 5.5 y, height = 1.78 ± 0.09 m, body mass = 80.8 ± 15.3 kg) completed four twelve-minute bouts of treadmill walking (3.5, 5.5, 6.5 $km \cdot hr^{-1}$, and self-selected [5.0 ± 0.2 $km \cdot hr^{-1}$]) while carrying 21 kg of load in a free arm swing condition with a weighted vest (front 12 kg, back 6 kg), and in a restricted arm swing condition with a portion of the anterior vest mass held in the hands (replica F88 Austeyr; 3.2 kg). Physiological measures included expired respiratory gases and heart rate, which was averaged during the final three-minutes of each bout. Biomechanical measures included flexion-extension angles of the hip, knee, and ankle collected using a three-dimensional motion capture system. Statistical analyses to assess the interaction and main effects of walking speed and weapon handling included linear mixed models (expired gases and heart rate) and repeated measures analyses of variance using statistical parametric mapping (time-normalised joint angles). Data are presented as mean difference ± standard error. **Results:** There were several interaction effects of speed and weapon ($p < 0.05$), whereby weapon handling increased oxygen consumption (2.7 ± 0.7 $mL \cdot kg^{-1} \cdot min^{-1}$), carbon dioxide production (0.21 ± 0.04 $L \cdot min^{-1}$), and heart rate (7 ± 2 $b \cdot min^{-1}$) compared with free arm swing at 6.5 $km \cdot hr^{-1}$. There was a main effect of weapon handling ($p < 0.05$) for expired ventilation, whereby it increased with weapon handling (1.58 ± 0.63 $L \cdot min^{-1}$) when compared with free arm swing. There were no interaction nor main effects of weapon handling for any joint angles ($p > 0.05$). **Conclusions:** The observed increase in physiological responses caused by weapon carriage and subsequent restricted arm swing was not explained by lower limb kinematic differences. The greater physiological demands observed at the fastest walking speed of 6.5 $km \cdot hr^{-1}$ is the likely result of the isometric muscle contractions required to hold and stabilise the weapon. **Military Impact:** The increased physiological response during weapon handling at the faster speed (e.g., movement to contact) may have implications for subsequent task performance such as marksmanship.

09:15 – 09:30: Cardiorespiratory responses to torso-borne loaded marching in British Army Infantry soldiers & physically active civilians

Josh Osofa [1], Gemma Milligan [2], Mike Tipton [2], Nicola Armstrong [1], Mitch Lomax [2]

[1]Defence Science and Technology Laboratory, UK
[2]University of Portsmouth, UK

Purpose: It was unknown whether the cardiorespiratory responses to load carriage (LC) differed between military personnel with LC experience and physically active civilians. A comparison between the two groups would inform the transferability of data captured in civilians from LC studies to military populations. It was hypothesised that the cardiorespiratory strain of LC would be lower in infantry soldiers with LC experience than in physically active civilians. Methods: Seventeen male British Army infantry soldiers with recent LC experience, (mean ± SD, age 23 ± 6 y, body mass 81.7 ± 10.4 kg, height 1.79 ± 0.06 m) and 14 physically active male civilians with no prior LC experience (age 22 ± 3 y, body mass 76.0 ± 11.8 kg, height 1.79 ± 0.08 m) completed two trials on separate days (unloaded and donning 25 kg of load). Each trial involved a 50-min treadmill march (4.8 km·h-1, 0% incline) during which oxygen uptake (VO_2), carbon dioxide output (VCO_2), end-tidal oxygen pressure ($P_{ET}O2$), end-tidal carbon dioxide pressure ($P_{ET}CO_2$), and heart rate (HR) were recorded. Three-way mixed-model ANOVAs determined any main effects and interactions with group (military, civilian), time point (start, mid, end), and condition (unloaded and loaded). Alpha was set at $p < 0.05$. Results: The infantry soldiers had a greater $P_{ET}O_2$ (military: 104.60 ± 4.26 mmHg, civilian: 101.90 ± 3.05 mmHg; $p = 0.027$) during unloaded and loaded marches. No other main effects were detected for group. VO_2, VCO_2, and $P_{ET}O2$ increased with time ($p = 0.001 – 0.005$) during unloaded and loaded marches. $P_{ET}CO_2$ decreased with time ($p < 0.001$) and with load ($p = 0.030$). VO_2 and VCO_2 were greater during the loaded march ($p < 0.001$) compared with unloaded. An interaction between time point and condition revealed that HR was greater ($p = 0.006$) at each time point with LC. Conclusions: These findings show that both groups exhibited similar cardiorespiratory responses to 25 kg loaded marching. Therefore, the hypothesis is rejected. Furthermore, physically active civilians may be used to assess cardiorespiratory strain in 25 kg LC studies. Military Impact: The use of civilians in LC studies has previously been seen as a limitation for its application for the military. However, this study provides evidence that 25 kg LC studies using physically active civilians to collect cardiorespiratory data may be transferrable to military populations. These findings can be used to inform future method development of LC studies.

09:30 – 09:45: Respiratory muscle strength in British Army infantry recruits

Nicola Armstrong [1], Katrina Hinde [1], Josh Osofa [1], Will Furby [1], Stuart Bailey [1]

[1]Defence Science and Technology Laboratory, UK

Purpose: This study aimed to identify if respiratory muscle strength increases in infantry recruits during basic training. **Methods:** Seventy-six infantry recruits undertaking basic training volunteered to participate in the study. Participants were recruited in two cohorts;

data collection for cohort 1 (n = 39) was conducted from August 2022 to October 2022 and Cohort 2 (n = 37) from Jan 2023 to March 2023. The strength of the inspiratory and expiratory muscles was assessed at Week 1, Week 6, and Week 12 of basic training by measurement of maximum inspiratory and expiratory mouth pressures (MIP and MEP, respectively). Review of individual data were conducted to identify individuals that may benefit from an intervention designed to increase respiratory muscle strength. One-way repeated measures ANOVAs and t-tests were used to identify differences in group means over the 12 weeks. **Results:** Thirty-five of 76 recruits completed the study. No changes in body mass were observed during the study ($p = 0.313$, $d = 0.03$). MIP increased by 13% ($p = 0.001$, $d = 0.50$) and MEP by 12% ($p = 0.001$, $d = 0.47$) during the 12 weeks. At Week 1, 40% of participants recorded mouth pressures below predicted values (based on age); this reduced to 7% at the end of Week 12. **Conclusions:** 40% of participants entered infantry basic training with weak respiratory muscles that were below aged predicted values. Basic training increased both inspiratory and expiratory muscle strength, however despite these improvements, 7% of recruits still exhibited weak respiratory muscles at Week 12. These individuals would benefit from an intervention designed to increase respiratory muscle strength. **Military Impact:** The respiratory muscles play a critical role during exercise. Military personnel are at risk of developing respiratory muscle fatigue (RMF) during training and operations. RMF has a detrimental effect on exercise performance. The contribution of the respiratory muscles to postural stability is attenuated when respiratory demand increases. As such RMF could compromise stability of the spine during military tasks. Strategies to strengthen the respiratory muscles and reduce the impact of RMF are available, which have proven benefit in clinical and athletic populations. This study has identified where these strategies could be applied in the military environment to reduce the risk of RMF on military task performance.

09:45 – 10:00: The impact of torso-borne load-carriage on operating lung volumes and breathing patterns during marching in British Army Infantry soldiers and physically active civilians

Mitch Lomax [1], Josh Osofa [2], Mike Tipton [1], Nicola Armstrong [2], Gemma Milligan [1]

[1]University of Portsmouth, UK
[2]Defence Science and Technology Laboratory, UK

Purpose: This study compared the impact of load carriage (LC) experience on operating lung volumes and breathing patterns during unloaded and loaded marching between infantry soldiers with LC experience and physically active civilians with no LC experience. **Methods:** Seventeen male British Army infantry soldiers (mean ± SD, age 23 ± 6 y, body mass 81.5 ± 10.4 kg, height 1.79 ± 0.06 m) and 14 physically active male civilians (age 22 ± 3 y, body mass 76.0 ± 11.8 kg, height 1.79 ± 0.08 m) completed two trials on separate days (unloaded and donning 25 kg of load). Each trial involved a treadmill 50 min march (4.8 km·h-1, 0% incline) during which expired air was recorded for the determination of minute ventilation (V_E), tidal volume (VT) and breathing frequency (bf). End-expiratory lung volume (EELV) and end-inspiratory lung volume (EILV) were calculated by superimposing tidal breaths within the maximal flow volume loop determined at rest and expressed as a percentage of forced vital capacity (FVC). Three-way

mixed-model ANOVAs (SPSS Statistics, v.28) determined any main effects and interactions with time point (V_E, bf, VT: rest, start, mid, end; EELV, EILV: rest, 10-min, 20-min 30-min, 40-min), group (soldiers, civilians) and condition (unloaded, loaded). Alpha was set at $p < 0.05$. **Results:** There was no effect of group on any variable. Exercising EILV was increased with load (unloaded: 48-53% of FVC; loaded: 56-61% of FVC, $p < 0.001$). EELV was increased with load (unloaded: 29-36% of FVC; loaded: 34-40% of FVC, $p < 0.001$) but remained similar throughout exercise. V_E was increased during exercise in the loaded trial (unloaded: 26.8-30.7 $L{\cdot}min^{-1}$; loaded: 33.3-39.7 $L{\cdot}min^{-1}$, $p < 0.001$) and also increased throughout exercise in the loaded trial ($p < 0.05$). bf was increased (unloaded: 23-29 $b{\cdot}min^{-1}$; loaded: 31-38 $b{\cdot}min^{-1}$, $p < 0.001$) and VT was reduced (unloaded: 1.09-1.24 L; loaded: 1.06-1.14 L, $p < 0.001$) throughout exercise when wearing load. VT was decreased during exercise ($p = 0.005$). **Conclusions:** Operating lung volumes and breathing pattern during unloaded and loaded marching were unaffected by LC experience. Marching with 25 kg of load increased V_E and bf but reduced VT compared with unloaded marching. Marching with load also increased exercising EILV and EELV compared with unloaded marching. **Military Impact:** Prior LC experience did not protect against the changes in operating lung volumes or breathing pattern exhibited during loaded marching. Such changes may increase the work of breathing and likelihood of breathing muscle fatigue, which could reduce exercise tolerance and subsequently impair soldier physical performance.

Thematic Sessions 24 to 27

Thursday 14th September, 10:15 to 11:45

Thematic 24: Epidemiology of musculoskeletal injuries in female military personnel: descriptive data and risk factors

Main Room

Description

This session will explore the unique issues impacting women in the military, including the consistently high risk of musculoskeletal injuries. The session will provide an overview of the epidemiology of injuries among female military personnel. Presentations in the session will include an exploration of the injury profiles and relative risks of injury among U.S. Army women compared to men, both historically and more recently with gender integration; an analysis of bone stress injuries during Army basic combat training; and the epidemiology of injuries during Marine Corps recruit training. Issues that are unique to women in the military will be discussed, including the types of injuries and factors associated with injuries in Servicewomen during pregnancy. The aim of the session will be to improve understanding of the potentially preventable injuries that cause a greater burden on women compared to men in the military.

Background

In spite of many years of research, women in the military are at increased risk of musculoskeletal injuries compared to men. With increasing levels of gender-integration in the United States and around the world, women are being increasingly employed in physically arduous military occupational specialties. The employment of women in these roles can increase the risk of injuries and adverse physiological outcomes. In addition, a unique aspect of women's health is pregnancy, and as women integrate into ground combat roles in the military, maintaining health and fitness levels during pregnancy and improving fitness postpartum while minimising risks of injuries are imperative.

Military Impact

With many militaries around the world opening ground combat roles to women, increasing numbers of women are expected to join the military now and in the future. The integration of women in these roles presents a unique challenge and opportunity for decision makers. A better understanding of the burden of musculoskeletal injuries among female military personnel, comparison between genders, and assessment of the risk factors for injuries among women will provide important information for military leaders and researchers in this field. Understanding the burden and risk factors for injury can help in the design of customised, sex-specific injury prevention and performance optimisation programs aimed at preventing musculoskeletal injuries and enhancing tactical readiness among the increasing number of women in combat roles. Findings from these studies can also be applicable to women in other physically strenuous occupations, such as first responders and athletes.

Presentations

Chair: *Mita Lovalekar, University of Pittsburgh, USA*

10:15 – 10:35: Injuries among women following U.S. Army gender integration

Michelle Canham-Chervak, Defense Centers for Public Health – Aberdeen, USA

10:35 – 10:55: Bone stress injuries during U.S. Army Basic Combat Training: a retrospective analysis, fiscal years 2018-2021

Ryan Steelman, Defense Centers for Public Health – Aberdeen, USA

10:55 – 11:15: Descriptive epidemiology of musculoskeletal injuries during Marine Corps Recruit Training in gender-integrated and male only training units

Mita Lovalekar, University of Pittsburgh, USA

11:15 – 11:35: Factors associated with injuries in Servicewomen during pregnancy

Esther Dada, Defense Centers for Public Health – Aberdeen, USA

11:35 – 11:45: Questions and discussion

Thematic 25: Internal dialogue: deciphering the role of the gut microbiome in health and performance

Room 1

Description

We are all mostly microbe: there are more microbial cells in and on us than human cells. There are over 2 lbs of microbes in our gut alone. These microbes are essential to our survival: they digest recalcitrant parts of our diet, produce essential vitamins and metabolites, and prevent the establishment of microbes that may cause health issues. Unlike our own genome, the community of microbes that resides in our gastrointestinal (GI) tract—our gut microbiome—can be modulated through changes in diet, and utilising prebiotics, probiotics, and engineered probiotics. This session aims to explore how the gut microbiome responds to military-relevant stressors such as environmental pathogens, circadian rhythm disruption, and cognitive fatigue, and aims to explore potential ways to promote resiliency through gut microbiome modulation.

Background

The gut microbiome is impacted by a range of environmental and lifestyle factors including diet, antibiotics, physical fitness, and acute/chronic stressors. There is evidence that suggests that specific components of the gut microbiome are mediators of aspects of health and performance including disease susceptibility, cognitive/physical states, and the immune response. Diarrhoeal disease is a significant cause of Disease Non-Battle Injury for deployed military personnel. The rate of self-reported travellers' diarrhoea during two Op HERRICK deployments to Afghanistan was approximately 40%, with an average of 4 underperforming days per episode. Understanding microbe:microbe and nutrient:microbe interactions in the gut and how it interacts with other organs (e.g., gut-brain axis) will enable better design of interventions aimed at modulating the gut microbiome to improve the health and performance of the military.

Military Impact

The burden of GI infections should not be underestimated, and the incapacitating nature of such admissions would put nations at a disadvantage with regards to operational effectiveness. An improvement in the way these infections are prevented or treated would have a huge impact on the health and performance of military personnel. Gut microbiome modulation enables a non-invasive approach to build resiliency to both negative health states and performance optimisation. Having a better understanding of the gut, the gut microbiome, and its effects throughout the body would enable a pre-positioning in advance of a deployment which could reduce lost days, improve effectiveness, enhance survivability, and increase lethality. In addition, such findings could be exploited by a civilian population, who also suffer from the burden of GI distress—such as traveller's diarrhoea—and suboptimal performance states.

Presentations

Chair: *Sarah Harding, Defence Science and Technology Laboratory, UK; Emily Parish, Defence Science and Technology Laboratory, UK*

10:15 – 10:30: Travelers diarrhoea in the UK military

Jo Rimmer, Royal Air Force, UK

10:30 – 10:45: The role of the gut microbiome in deployment health and performance

Mike Goodson, US Air Force Research Laboratory, USA

10:45 – 11:00: Understanding gut microbiome functional capacity to identify interventions to modulate health and performance

Jason Soares, US Army DEVCOM Soldier Center, USA

11:00 – 11:15: The gut microbiome as a target for improving performance

Tom Troth, British Army, UK

11:15 – 11:30: Understanding the multidirectional axes of communication between the gut microbiome and the brain to augment human performance

Gerard Clarke, University College Cork, Ireland

11:30 – 11:45: Questions and discussion

Thematic 26: Exertional heat illness and recovery or return to duty: international lessons learned and best practices for the future

Room 2

Description

The goal of this thematic session is to discuss the different approaches of preventive heat management and decision-making process for return to duty (RTD) after exertional heat illness / exertional heat stroke (EHI / EHS) across our international community. It is a multidisciplinary session that will include some aspects of basic science to clinical decision through applied physiology. As we still don't have all the answers, some innovative points will be presented for future research, experts' networks, and dedicated heat centres. First, an epidemiologic frame and definition of different EHI will be presented and the necessity of an international task force. Secondly, after a brief description of the context for each respective armed forces, different countries will present their own strategy of RTD and their various applied protocols. Novel approaches to improve decision making on RTD, including ongoing research studies designed to identify novel biomarkers and their interpretation, will be discussed.

Background

Sustained physical exertion is accompanied by significant metabolic heat production and consequently an increase in thermal strain that may put individuals at risk of EHI, and at the extreme, EHS. Minimising the risk of EHI requires accurate characterisation and identification of specific risk factors across the range of EHI severity. Equally important are decisions regarding when and how to allow a warrior who has clinically recovered from EHI / EHS to RTD. For these two steps, the challenging medical issue is to know: (1) if these factors are modifiable, and; (2) how to assess the risk of a second event. Among a range of clinical tools, heat tolerance assessment has been employed to predict future risk and to manage the individual's status. But the decision on RTD in military medicine is complex and depends on multiple factors that vary from country to country.

Military Impact

Although guidelines exist for successful prevention and treatment of heat injuries, questions remain regarding our ability to return warriors objectively and safely to duty following EHS. Military physicians may lack sufficient information to make good RTD decisions. Inappropriately returning a warrior back to duty might endanger the lives of that individual and others, and incorrectly pulling a warrior from duty could unnecessarily cut short a valuable military career. Bringing more science to the clinical decision-making process may offer unit leaders a better understanding of the decision that was made, with the overall goal to lower the morbidity and mortality associated with training and exercise in hot environments to optimise unit operational capabilities and force readiness. The roundtable will propose the writing of a current consensus paper about RTD after EHS and will include an international panel of experts who share similar concerns and research interests in these areas.

Presentations

Chair: *Yoram Epstein, Tel Aviv University, Israel; Jason Lee, National University of Singapore, Singapore*

10:15 – 10:20: Heat tolerance testing: a historical perspective

Yoram Epstein, Tel Aviv University, Israel
Jason Lee, National University of Singapore, Singapore

10:20 – 10:30: Clinical classification of exertional heat stroke and implementation of heat tolerance testing. How could we distinguish circumstantial injury from individual vulnerability?

Alexandra Malgoyre, French Armed Forces Biomedical Research Institute, France

10:30 – 10:40: Heat illness prevention update: mechanisms and potential sex differences

Nisha Charkoudian, US Army Research Institute of Environmental Medicine, USA

10:40 – 10:50: Definition of heat injuries and heat management in Singapore: setting up of the Heat Resilience and Performance Center to explore strategies in partnership and establishing an International Heat Injuries Registry

Jason Lee, National University of Singapore, Singapore

10:50 – 11:00: The US Army Heat Center experience: a multidisciplinary care review process making the difference and lessons learned

Francis O'Connor, Uniformed Services University of the Health Sciences, USA

11:00 – 11:10: Heat tolerance assessment: how science is applied in the clinical / occupational decision-making process for return to duty and activity of UK Service Personnel post exertional heat illness

Omar Tayari, Institute of Naval Medicine, UK

11:10 – 11:20: Interpretation of the heat tolerance testing by objective indices: the IDF perspective

Itay Ketko, Israel Defense Forces Medical Corps, Israel

11:20 – 11:45: Roundtable discussion: can we reach a consensus on return to duty after an exertional heat stroke event?

Thematic 27: Evidenced-based interventions to decrease overuse musculoskeletal injury incidence in military training

Room 3

Description

Recently, militaries have reduced musculoskeletal injury incidence by critically investigating the physical demands imposed on candidates in military training programs such as basic training or in developmental periods. These are finite periods where candidates are required to follow a training program, including military exercises (on and off field) and physical training. The examination of the physical demands of these military exercises and the improvement of physical training and nutrition to resist these demands can decrease overuse musculoskeletal injury incidence. While it is unknown if the reduction in injuries is due to a decrease in physical training volume at certain periods throughout these courses or the improvement in physical fitness that increases the capacity to cope, the resulting success is encouraging. These presentations demonstrate the need to apply the evidenced based approach to physical training in the military (Canada, Australia, and the UK), employing the knowledge of physical training expertise and nutrition whenever possible.

Background

Often in the military there is no standardised physical training plan for a course, and physical training mostly consists of callisthenic / body weight type exercises, running, and load carriage, without proper time for recovery between sessions, and without consideration for the other physical demands of the course. To reduce overuse musculoskeletal injury incidence, considerations of the physical demands and the most common musculoskeletal injuries, and the development of a progressive training program—aimed at improving the ability to meet the physical demands of the course—and nutritional support to support musculoskeletal adaptation are required. This collection of studies is aimed at determining: (1) the demands of a variety of Army training courses; (2) the effect of a standardized progressive training program on reducing the risk of musculoskeletal injuries, and; (3) the effect of nutritional interventions on the musculoskeletal adaptations to military training.

Military Impact

The application of evidenced-based physical training interventions in the Canadian Army have resulted in a drastic (~50%) reduction in overuse musculoskeletal injury incidence. These talks will also demonstrate how trials with experimental interventions can be delivered to support militaries making evidence-based improvements to their training practices.

Presentations

Chair: *Tara Reilly, Canadian Forces Morale & Welfare Services, Canada*

10:15 – 10:30: How a modified physical training program was implemented on an infantry training course to reduce musculoskeletal injuries

Eric Robitaille, Canadian Forces Health Services, Canada

10:30 – 10:45: Effect of a standardized progressive training program to reduce overuse musculoskeletal injuries for Artillery Troop Commanders

Hans Christian Tingelstad, Canadian Forces Morale & Welfare Services, Canada

10:45 – 11:00: Effectiveness of a fitness screening test for Canadian Basic Military Training

Marie-Andrée Laroche, Canadian Force Moral & Welfare Services, Canada

11:00 – 11:15: The influence of a reduced external load and sprint intensity intervals on infantry trainees

Penny Larsen, Charles Sturt University, Australia

11:15 – 11:30: Nutritional interventions to support musculoskeletal adaptation to military training

Thomas J O'Leary, Army Health and Performance Research, UK

11:30 – 11:45: Questions and discussion

Oral Communication 18: Musculoskeletal Injury and Physiology

Thursday 14th September, 12:15 to 13:45

Main Room

Chair: *Thomas J O'Leary, Army Health and Performance Research, U*

12:15 – 12:30: Areal bone mineral density changes in soldiers attending U.S. Army Ranger training

William R Conkright [1], Charlotte V Coombs [2], Thomas J O'Leary [2], Julie P Greeves [2], Julie M Hughes [3], Nicholas D Barringer [4], Martha A Smith [5]

[1]Madigan Army Medical Centre, USA
[2]Ministry of Defence, UK
[3]US Army Institute of Environmental Medicine, USA
[4]US Army-Baylor Masters Programme in Nutrition, USA
[5]Overton Brooks VA Medical Centre, USA.

Purpose: Military personnel may experience an increase in areal bone mineral density (aBMD) during training as a result of mechanical loading, which stimulates bone growth and potentially remodelling. In contrast, low energy availability, often experienced during rigorous training, can result in loss of aBMD. Soldiers attending U.S. Army Ranger School experience both prolonged periods of weight-bearing physical activity, and sleep and caloric restriction. This study aimed to examine the effects of U.S Army Ranger School on aBMD where the competing effects of this multi-stressor training environment are unknown. **Methods:** Eighty-seven Soldiers (age: 23.2 ± 3.8 y, height: 1.8 ± 0.1 m, body mass: 81 ± 8 kg; body fat: 17.5 ± 4.6 %) from 2/75 Ranger Regiment attended U.S. Army Ranger School, a rigorous, 8-week course consisting of three phases. Soldiers that fail one or more phases may be retained and required to repeat phases, known as "recycling". Total and regional (arm, leg, spine) aBMD were determined by dual-energy X-ray absorptiometry machine. Calcium, parathyroid hormone, and 25-hydroxyvitamin D concentrations were measured from venous blood using standard assays. Outcomes were measured before (BL) training and two-weeks (2WK) and six-weeks (6WK) after completion of the 8-week training programme. aBMD and calciotropic biomarkers were compared over time with linear mixed effects models. **Results:** Thirty-five (40%) Soldiers graduated from Ranger School without recycling, 25 (29%) graduated after recycling at least once, 7 graduated but recycle status was missing (8%), and 20 (23%) did not graduate. Spinal aBMD decreased from BL to 2WK (1.22 ± 0.12, 1.20 ± 0.13 g·cm-2, p = 0.001) but was significantly higher at 6WK versus BL (1.27 ± 0.13 g·cm-2, p = 0.009). Total, arm, and leg aBMD as well as calcium, parathyroid hormone, and 25-hydroxyvitamin D did not change significantly (p > 0.05). Vitamin D status improved from 79% of individuals being deficient or insufficient (total 25-hydroxyvitamin D < 50 nmol·L-1) at BL to 43% at 2WK and 25% at 6WK. **Conclusions:** The decrease in axial aBMD observed following Ranger School, concomitant with prolonged periods of sleep loss and caloric restriction, was restored within 6 weeks postgraduation. The load bearing activities of military training possibly protects the appendicular skeleton in multi-stressor environments. Vitamin D status improved overtime, likely from enduring long hours training outdoors, whereas calcium and parathyroid hormone are more tightly regulated through homeostatic control. **Military Impact:** aBMD and markers of bone health are minimally impacted in highly fit Soldiers following rigorous, 8-week multistressor trainings comprised of loaded physical activity with energy and sleep restriction.

12:30 – 12:45: Acute and chronic high load intensity resistance exercise is associated with changes in bone-related biomarkers

Kristen J Koltun [1], Adam J Sterczala [1], Nicole Sekel [1], Kellen T Krajewski [1], Brian J Martin [1], Shawn Flanagan [1], Chris Connaboy [1], Sophie L Wardle [2], Thomas J O'Leary [2], Julie P Greeves [2], Bradley C Nindl [1]

[1]University of Pittsburgh, USA
[2]Army Health and Performance Research, UK

Purpose: Weight-bearing physical activity can stimulate bone adaptation directly via mechanotransduction by bone cells and indirectly via changes in the hormonal milieu. This investigation explored the effect of an acute bout of resistance exercise, and the potential influence of sex and training status, on biomarkers of bone metabolism and muscle-bone crosstalk. **Methods:** Healthy young men (n = 21, age 29 ± 1 y, BMI 26.6 ± 1.0 kg·m^{-2}, 24.7 ± 0.1% body fat) and women (n = 18, age 27 ± 1 y, BMI 24.1 ± 0.1 kg·m^{-2}, 30.6 ± 0.1% body fat) performed a 6 × 10 repetition squat test at 75% one-repetition maximum before and after a 12-week, laboratory controlled, military-specific, resistance and high-intensity interval training program (3 d·wk^{-1}, four mesocycles, linearly progressive intensity / mesocycle to improve peak force and power). Before and after completion of the 12-week training program, blood samples were collected at rest, immediately following the exercise test, and 2 h post-exercise and measured for ßCTX, PINP, sclerostin, osteocalcin, IGF-I, and irisin. Generalized linear mixed effects models tested the effects of sex (male, female), training status (baseline, 12 weeks), exercise (rest, post, recovery), and their interactions, on biomarker concentrations (α = 0.05). **Results:** Main effects of acute exercise ($p \leq 0.002$) were observed for IGF-I (+12%), irisin (+21%), osteocalcin (+27%), and PINP (+8%), wherein all concentrations increased immediately following the exercise bout and returned to resting concentrations within 2 h of recovery. Sex × exercise interactions were observed for ßCTX and sclerostin ($p \leq 0.020$); men had a greater decline in ßCTX concentrations from rest to recovery (–37 vs –26%) and a greater increase in sclerostin concentration from rest to post-exercise (+53 vs +38%) than women. Main effects of sex were also observed for irisin and PINP ($p \leq 0.002$); men had lower irisin (7.38 vs 10.41 ug·mL^{-1}) but higher PINP (66.9 vs 54.3 pg·mL^{-1}) concentrations than women. Osteocalcin was greater after completion of the 12-week program than before (main effect: $p = 0.021$; 22658 vs 20872 pg·mL^{-1}). A significant training × time interaction was observed for sclerostin ($p = 0.026$); concentrations increased following acute exercise at both timepoints (37 to 56%), but only remained elevated into recovery pre-training and returned to resting values in recovery following training. **Conclusions:** Changes in concentrations of biomarkers of bone metabolism and muscle-bone crosstalk, which may represent or promote adaptive bone formation, were observed in men and women after an acute bout of resistance exercise and following 12 weeks of resistance training. **Military Impact:** Exercise programs that incorporate higher relative load intensity resistance training to improve strength and performance of military tasks may also be beneficial for bone adaptation.

12:45 – 13:00: Lower baseline trunk areal bone mineral density, not cortical parameters, predicts greatest density changes at the axial skeleton in recreationally active men and women following 12 weeks of concurrent resistance training

Nicole Sekel [1], Adam J Sterczala [1], Kristen J Koltun [1], Kellen T Krajewski [1], Mita Lovalekar [1] , Kelly H Mroz [1], Sophie L Wardle [2], Thomas J O'Leary [2], Julie P Greeves [2], Shawn Flanagan [1], Chris Connaboy [3], Bradley C Nindl [1]

[1]*University of Pittsburgh, USA*
[2]*Army Health and Performance Research, UK*
[3]*Rosalind Franklin University, USA*

Purpose: The adult skeleton is composed of 80% cortical bone and sufficient evidence supports that the cortical compartment of bone bears the bulk of axial loads in the distal tibia. This study determined if cortical morphological and tissue level parameters are associated with density changes at the axial skeleton following exercise training. **Methods:** Recreationally active men (n = 21, age 29 ± 1 y, height 1.78 ± 0.02 m, body mass 84.3 ± 3.0 kg) and women (n = 18, age 27 ± 1 y, height 1.64 ± 0.01 m, body mass 65.0 ± 2.3 kg) underwent total body Lunar iDXA scans for trunk areal bone mineral density (aBMD, $g{\cdot}cm^{-2}$) and High-Resolution Peripheral Quantitative Computed Tomography (HR-pQCT) scans at the proximal tibial diaphysis (30% site) for volumetric BMD (vBMD) and micro-finite element analysis (µFEA). Scans were performed at baseline (T1) and post 12 weeks of concurrent resistance training (T2). To avoid issues of collinearity, two separate regression models were generated. Both models were controlled for sex and baseline trunk aBMD. Model 1 contained standard cortical parameters including: cortical tissue mineral density (Ct.TMD [mg $HA{\cdot}cm^{-3}$]), perimeter (Ct.Pm [mm]), area (Ct.Ar [cm^{-2}]), and thickness (Ct. Th [mm]). Model 2 included cortical µFEA parameters: whole bone stiffness [N·mm], apparent modulus [$N{\cdot}mm^{-2}$], cortical stress magnitude (Von Mises stress [$N{\cdot}mm^{-2}$]), and cortical tissue deformation (strain [µstrain])). **Results:** Overall, model 1 containing just sex, baseline trunk aBMD, and cortical deformation predicted 31% of the variation in the change in trunk aBMD from T1 to T2 ($F(3, 34) = 5.28$, $p = 0.004$, $R2 = 0.318$.) Only sex ($\beta = -1.30$, $p = 0.019$) and baseline trunk aBMD ($\beta = -7.90$, $p = 0.001$) had significant slope coefficients. Model 2 containing just sex, baseline trunk aBMD, and Ct.Th predicted 27% of the variation in the change in trunk aBMD from T1 to T2 ($F_{(4, 34)} = 4.26$, $p = 0.012$, $R^2 = 0.273$). Only baseline trunk aBMD ($\beta = -8.25$, $p = 0.002$) had a significant slope coefficient. **Conclusions:** These results suggest that those with lower baseline trunk aBMD predicted greater change in trunk aBMD from T1 to T2. These findings are in alignment with the Mechanostat Theory that posits that the least trained bones will experience the greatest strains in response to mechanical loading and will consequently experience the greatest magnitude of bone adaptation. **Military Impact:** Improvements in trunk aBMD may be particularly beneficial to female recruits as they disproportionally suffer stress fractures of the pelvis, an anatomical site elatioed in the DXA trunk parameter.

13:00 – 13:15: Sleep characteristics associated with musculoskeletal injuries in female Canadian Armed Forces members

Jessica L Puranda [1], Chris M Edwards [1], Sara S Souza [1], Danilo F da Silva [2], Taniya S Nagpal [3], Kevin Semeniuk [1], Kristi B Adamo [1]

[1]*University of Ottawa, Canada*
[2]*Bishop's University, Canada*
[3]*University of Alberta, Canada*

Purpose: Musculoskeletal injuries (MSKi) are common among military personnel, with female service members being at greater risk than their male peers. Sleep is a critical physiological requirement with a bi-directional relationship with several factors including cardiovascular, metabolic, and mental health. Moreover, poor sleep hygiene is considered a risk factor for MSKi. Other factors such as older age, higher BMI, being a non-commissioned member (NCM), parenthood, having an irregular menstrual cycle, and having a physically demanding occupation have been linked to both poor sleep characteristics and increased risk of MSKi. A comprehensive investigation into the relationship between sleep and MSKi among female Canadian Armed Forces (CAF) members has yet to be carried out. This study seeks to determine the prevalence of dysfunctional sleep and the association between sleep and MSKi history among female CAF members with consideration given to female-specific factors. **Methods:** Active and released CAF members aged 18 to 65 years responded to an electronic survey (SurveyMonkey®) between September 2020 and February 2021. Demographics, self-reported reproductive characteristics, and MSKi outcomes were collected. Sleep quality was measured by the Pittsburgh Sleep Quality Index (PSQI). Bivariate associations were used to determine covariates. Logistic regressions were used to analyse the relationships between sleep characteristics and acute and repetitive strain injuries (RSI). **Results:** Seven-hundred and sixty-five active-duty female members responded to the online survey. The prevalence of a Global PSQI score ≥ 6, indicative of poor sleep hygiene, was 61.3%. When the model was adjusted for age, rank structure (i.e., NCM or officer), and occupational physical demand, i) sleep duration < 7 h (adjusted odds ratio (aOR): 1.676, 95% confidence interval [1.169, 2.402]), ii) day time dysfunction (aOR: 1.800 [1.181, 2.743]), and iii) a Global PSQI score ≥ 6 (aOR: 1.624 [1.107, 2.381]) were associated with a greater chance of having experienced an acute injury. Daytime dysfunction (aOR: 1.731 [1.092, 2.744]) and a Global PSQI score ≥ 6 (aOR: 1.533 [1.004, 2.341]) were associated with an increased chance of having experienced a RSI when adjusted for age, BMI, parenthood, and menstrual regularity. **Conclusions:** The prevalence of sleep dysfunction among female CAF members is high. Sleep quality and daytime dysfunction are associated with both acute injury and RSI among active female CAF members. Sleep duration of ≤ 7 h was associated with acute injury. **Military Impact:** When designing strategies to reduce the occurrence of MSKi among female CAF members, one should consider sleep hygiene as a potential target for intervention.

13:15 – 13:30: Externally validated machine learning algorithm accurately predicts medial tibial stress syndrome in military trainees: a multi-cohort study

Angus Shaw [1], Phil Newman [2], Jeremy Witchalls [2], Tristan Hedger [3]

[1]University of Canberra, Australia
[2]University of Canberra Research Institute for Sport and Exercise, Australia
[3]Duntroon Health Centre, Australia

Purpose: Medial Tibial Stress Syndrome (MTSS) has been identified as the costliest musculoskeletal injury to the British Army, affecting 35-80% of military trainees. There is no reliable treatment, and reoccurrence rates are high. Injury prediction is complex, multivariate, and has not been capable of discerning individual level risks. Therefore, prevention of MTSS is critical to reducing operational burden. This study aimed to build a decision-making model to predict the individual risk of MTSS within first year Australian Defence Force Academy Officer cadets and test the external validity of the model on a separate military population. **Methods:** Using a prospective design, this study collected a suite of key variables, determined in a previous study of Navy recruits, in a new population from the Australian Defence Force Academy. Data was obtained from 107 recruits (35 women and 75 men). Follow-up was conducted at 3 months to determine MTSS diagnoses, when a total of 99 recruits (69 men, 30 women) remained for inclusion in statistical analysis. Six ensemble learning algorithms—Decision Tree, Support Vector Machine, Logistic Regression, K- Nearest Neighbour, Random Forest, and Naïve Bayes—were deployed and trained five times on random stratified samples of 75% of the dataset. The resultant algorithms were tested on the remaining 25% of the dataset and the models were compared for area under the curve, classification accuracy, F1, precision, and recall. The most accurate new algorithm was tested on an unrelated data sample of 123 Australian Navy recruits to establish external validity of the model. **Results:** 35 / 99 cadets developed MTSS. Random Forest modelling was the most accurate in identifying a diagnosis of MTSS (area under the curve = 98%; classification accuracy = 96%, precision = 96%, recall = 96%). When the model was tested on an external dataset, it performed with similar accuracy (area under the curve = 95%; classification accuracy = 94%, precision = 89%, recall = 86%). Variables in the model included MTSS history; running experience/distance/ frequency; Ankle, hip, and foot mobility, BMI, orthotic use, and sex. **Conclusions:** This model is highly accurate in predicting those who will develop MTSS. The model provides important preventive capacity which should be trialled as a risk management intervention. Once an individual's risk of MTSS is calculated, targeting the modifiable risk factors may serve as the strongest preventative measure for this difficult to treat condition. **Military Impact:** Military institutions, clinicians, and instructors are now equipped with a low cost and user-friendly decision-making model, allowing accurate and individual level risk predictions for future MTSS development.

13:30 – 13:45: Predictors of musculoskeletal injury during U.S. Army Basic Combat Training

Stephen A Foulis [1], Kathryn M Taylor [1], Barry A Spiering [1], Leila A Walker [1], Katelyn I Guerriere [1], Susan P Proctor [1], Julie M Hughes [1]

[1]U.S. Army, USA

Purpose: Trainees who sustain a musculoskeletal injury (MSKI) during U.S. Army Basic Combat Training (BCT) are three times more likely to be discharged than those not injured, leading to substantial workforce and financial costs and reductions in military readiness. Determining risk factors for sustaining a MSKI during BCT will identify targets for potential interventions to mitigate injury rates during training. **Methods:** 1171 female and 1919 male trainees had their body composition measured by dual-energy X-ray absorptiometry, lower-body power by vertical jump, and blood biomarkers of bone formation / resorption, metabolism, and nutritional status measured during the first week of BCT. Surveys were also collected to capture lifestyle factors present prior to BCT, including physical activity, health, and medication usage, eating behaviours, sleep, and psychological characteristics. Army records data were used to identify pre-enlistment Occupational Physical Assessment Test scores and medically documented injuries that occurred during BCT. Bivariate logistic regressions were used as an initial screen to reduce the number of potential covariates into the MSKI risk model. Separate optimised full models by sex were developed using LASSO regression with internal cross validation, and receiver operator characteristic area under the curve (ROC-AUC) was calculated for each model to estimate model effectiveness. **Results:** Overall, 59% of females (n = 692) and 31% of males (n = 611) had at least one medically documented MSKI during BCT. Models were developed with ROC-AUC of 0.63 for females and 0.64 for males. For females, race, BMI, serum iron, body fat percentage, lean mass, physical activity history, sleep quality / quantity, deadlift strength, and upper body power collectively predicted MSKI. For males, body fat, serum vitamin D, physical activity history, lower body power, aerobic capacity, psychological grit, and sleep duration collectively predicted MSKI. **Conclusions:** Interventions targeting physical fitness, body composition, sleep, and psychological grit before BCT may provide an opportunity to reduce MSKI during training. **Military Relevance:** Developing interventions that modify these identified MSKI risk factors before BCT may reduce injury prevalence during training. **Disclaimer:** The views expressed in this abstract are those of the authors and do not reflect the official policy of the Department of Defense.

Oral Communication 19: Health and Wellbeing

Thursday 14th September, 12:15 to 13:45

Room 1

Chair: *Tara Reilly, Canadian Forces Morale & Welfare Services, Canada*

12:15 – 12:30: Effects of an operational physical training program applied during service on the body composition and oxidative stress of military policemen

Fernanda Monma [1], Lucas P Correia [1], Gilvan AR Mamede [1], Thabata Chaves Pereira Lima [1], José R Moura [1], Leonardo T Costa [1], Danielle S Dias [2], Kátia De Angelis [2], Diego R de Souza [1], Fernando A Santa Rosa [1]

[1]Military Police of the State of São Paulo, Brazil
[2]Federal University of São Paulo, Brazil

Purpose: Oxidative stress play an important role in the onset of cardiovascular disease. However, there is little evidence of the effect of operational physical training performed during military police service on oxidative stress markers. In addition, several clinical studies have demonstrated an increased number of oxidative stress markers in sedentary and obese individuals. The objective of this study was to compare hemodynamic parameters, oxidative stress, and body composition of sedentary military police officers with overweight or obese, submitted to 12 weeks of training. **Methods:** Fifty-eight male police officers, sedentary or insufficiently active, were selected for the study. Anthropometric analyses and a hemodynamic profile were performed. The military police officers underwent 12 weeks of operational physical training, twice per week, lasting 45 min per session. Oxidative stress markers were measured before the program of training and after the end of the 12-week period. **Results:** The results demonstrated that the training increased lean mass (62.7 *vs* 63.6 kg [95% CI of mean change, 0.4 to 1.5 kg]) and decreased body fat (27.6 *vs* 26.0 % [95% CI, −2.1 to −1.0]). A significant reduction in diastolic blood pressure (86.2 *vs* 83.7 mmHg [95% CI, −4.6 to −0.3]) was observed, but no significant changes in systolic blood pressure (133.1 *vs* 130.8 mmHg [95% CI, −5.9 to 1.3]). Training did not significantly change H_2O_2 levels (0.19 ± 0.11 vs 0.21 ± 0.16 microMolar). However, training was able to significantly reduce the activity of the pro-oxidant enzyme NADPH-oxidase (0.04 ± 0.03 *vs* 0.02 ± 0.04 microMolar·min·mg). The training did not change the nitrite values (2.2 ± 1.8 *vs* 1.9 ± 1.4 N·mg-1 of protein). Regarding the antioxidant capacity, a significant increase in the non-enzymatic antioxidant capacity was observed (10.1 mM Fe(ii) [95% CI, 3.5 to 16.8]). However, there was no change in catalase enzyme activity (0.01 nmol·mg^{-1} [95% CI, −0.67 to 0.67]). There was also a reduction in lipoperoxidation (−2.4 pmoles·mg^{-1} [95% CI, −3.7 to −1.1]), but no change in protein carbonyl levels (0.15 nmol·mg^{-1} [95% CI, −0.22 to 0.51]). **Conclusions:** The results demonstrate that an operational physical training program, carried out only twice a week, can positively modulate the antioxidant capacity and reduce the rate of systemic lipoperoxidation, altering the body composition. **Military Impact:** The increase in lean mass and the reduction in body fat have a positive impact on the operational performance of the military police. The improvement in the levels of oxidative stress markers demonstrate a positive effect on the health of the military.

12:30 – 12:45: Self-reported intentions to seek medical attention for musculoskeletal injuries, concussions, and exertion-related injuries during military training

Alex B Gregory [1], Carolyn E Dartt [1], Joshua L Waters-Jackson [1], Sarah J de la Motte [1]

[1]Uniformed Services University, USA

Purpose: Little is known about Service Members' intentions to seek medical attention for future musculoskeletal injuries (MSKI), concussions, or exertion-related injuries (ERI), and whether intentions vary based on the type of condition. Our goal is to describe recently enlisted Marines' intentions to seek medical attention during military training for MSKI, concussions, and ERI, and to assess differences in intention to seek medical attention by condition type. **Methods:** Recently enlisted male U.S. Marines identified self-reported intentions to seek medical attention for MSKI, concussions, and ERI using a 5-point Likert-style scale for: (1) "I would always seek medical attention if I have a MSKI during military training," (2) "I would always seek medical attention if I have a concussion during military training," and (3) "I would always seek medical attention if I have an exertion-related injury during military training." Responses ranged from "strongly agree" to "strongly disagree," and were collapsed into categories of "agree," "disagree," and "neutral". Friedman's test was used to assess differences in intention to seek medical attention for the three conditions (MSKI, concussion, and ERI). Post-hoc pairwise comparisons were performed using Wilcoxon signed-rank tests to compare intention to seek medical attention for (1) MSKI *vs* concussion, (2) MSKI *vs* ERI, and (3) concussion vs ERI. **Results:** Three-hundred and thirty-three Marines (age: 19.8 ± 1.8 y) completed the questionnaire. Friedman's test revealed a significant difference in Marines' reported intentions to seek care for MSKI, concussion, and ERI ($p < 0.001$). Pairwise comparisons showed Marines' significantly greater agreement with "I would always seek medical attention if I have a concussion during military training" (agree: 56.8%; neutral: 26.7%; disagree: 16.5%) compared to ERI (agree: 44.4%; neutral: 32.7%; disagree: 22.8%) ($p < 0.001$) and MSKI (agree: 42%; neutral: 30.3%; disagree: 27.6%) ($p < 0.001$). There was no difference for "I would always seek medical attention if I have a MSKI during military training" and "I would always seek medical attention if I have an ERI during military training" ($p = 0.08$). **Conclusions:** Marines reported greater intention to seek medical attention for concussions during military training than MSKI or ERI, suggesting perceptions that concussions are more worthy of medical attention, or that MSKI and ERI may be less serious or more manageable without medical attention. **Military Impact:** Encouraging early reporting of MSKI, concussions, and ERI could reduce severity and decrease training delays. Implementing specific education about these conditions during training could provide an early opportunity to address knowledge gaps and encourage Marines to seek early treatment.

12:45 – 13:00: The association of barriers with care-seeking for musculoskeletal injuries in Canadian military personnel using scenario-based questionnaires

Jennifer Born [1], Christine Frank [1], Min Xi [1]

[1]Department of National Defence, Canada

Purpose: Accessing appropriate care for physical injuries can reduce treatment times and improve treatment outcomes. Evidence suggests that military personnel experience barriers which can reduce care seeking. Further, the impact of barriers on accessing care can differ by the condition requiring treatment. Research exploring barriers and their impact on access to care for physical health in the military context is limited. This study quantifies the prevalence of a variety of barriers to seeking care in Canadian Armed Forces (CAF) personnel and measures the potential impact of those barriers on accessing care. **Methods:** A representative sample of CAF personnel (n = 1,190) responded to an online survey to quantify barriers, which contained questions on care-seeking in response to a hypothetical physical health scenario as a proxy for accessing care behaviour. Based on a factor analysis, 52 barrier items were grouped into seven factors representing a breadth of barrier issues related to capabilities, opportunities, and motivations to access care in the military context. Two additional factors were created for theoretical reasons to explore moral concerns. Barrier prevalence was estimated by item weighted to the CAF population, and barrier factor scores were calculated. Associations between barriers and not accessing care for a musculoskeletal injury were assessed using logistic regression. **Results:** Three barrier statements related to career consequences and one related to systemic care issues were endorsed by more than half of the sample, including: "Accessing care could prevent me from going on course or deploying", "Wait times for care are long", "If I access care, I could be given medication or a diagnosis that would interfere with my ability to do my job in the short-term", and "Accessing care can result in my being medically released". In models controlling for intentions, individual characteristics and additional behavioural constructs, barriers related to resources (e.g., a lack of time) and moral concerns (e.g., the belief that others are a higher priority for care) remained associated with not accessing care in the musculoskeletal injury scenario. Additionally, intentions to access physical health care and being male were associated with increased likelihood of accessing care in the models. **Conclusions:** Barriers related to resources and moral concerns may reduce access to care for a musculoskeletal injury, even in individuals who have intentions to access care when needed. **Military Impact:** In high tempo environments, scheduling and care-seeking priorities need to align to reduce barriers to accessing care for musculoskeletal injuries.

13:00 – 13:15: Sleep in British Army basic training: an observational analysis

Alex J Rawcliffe [1], Shaun Chapman [1], Bethany J Moxham [1], Harry Britt [1], Julia Rushmere [1], Amelia Morgan [1], Andrew J Roberts [1]

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Purpose: Sleep is essential for recovery from training and operational stressors, with the negative implications of poor sleep on health, wellbeing, and performance well established. Despite a growing awareness of the importance of sleep, military culture largely accepts sleep restriction and/or deprivation as a normal part of basic training (BT). Evidence suggests many perceive the need for sleep as a "weakness" or to "toughen up" recruits as part of their socialisation into BT. The aim was to determine sleep duration and quality in and across BT units compared to national recommendations to identify key areas for improvement. **Methods:** Sleep duration and perceptions of sleep quality were recorded (weekly) using validated wearable technology (*i.e.*, wrist-based actigraphy or sleep ring [Oura]) and sleep questionnaires during the initial 12-weeks of BT, including standard entry (SE, n = 215) and infantry (Line and Para, n = 40) recruits, and junior soldiers (JS, n = 37). Published data from Officer cadets (Ocdts, n = 26) using similar methods was included as part of this study. **Results:** The average total sleep time (TST) marginally differed between BT units (SE: 05:48 ± 00:45 hh:mm; Line: 05:37 ± 00:49 hh:mm; Para: 06:07 ± 00:34 hh:mm; JS: 06:37 ± 00:45 hh:mm; Ocdts: 05:29 ± 01:20 hh:mm), with >90% of all participants experiencing substantial sleep restriction during BT relative to national recommendations (i.e., 7-9 $h \cdot day^{-1}$). Similarly, the average time in bed (SE: 06:30 ± 02:10 hh:mm; Line: 06:10 ± 00:42 hh:mm; Para: 06:58 ± 00:43 hh:mm; JS: 06:51 ± 00:32 hh:mm; Ocdts: 06:52 ± 02:20 hh:mm) demonstrates poor sleep scheduling and, in part, explains the poor TST observed. The average time awake after sleep onset ranged from 00:31 ± 00:13 hh:mm to 01:05 ± 00:10 hh:mm, suggesting poor sleep hygiene within the main sleep environment. Factors reported to disrupt sleep during BT (less Ocdts) included: insufficient time to sleep (82%); phone/tablet use (>54%); excessive noise (28-45%); light (27-41%); discomfort (e.g., mattress, 28%), and stress / anxiety (19%). Other key sleep disturbing factors involved routine early morning wake times and late-night military admin. Despite no evidence of sleep issues/ disorders prior to BT, 10-45% and 30-41% of JS and Infantry Para recruits reported moderate-to-severe excessive daytime sleepiness and moderate-to-severe clinical insomnia symptoms during BT, respectively. **Conclusions:** Sleep quality and duration in and across BT units is inadequate. The negative implications of poor sleep likely place trainees at greater risk of injury, illness, and a poorer lived experience during BT. **Military Impact:** This study provides Army leadership with the required knowledge to target key issues contributing to poor sleep duration and quality in BT to enhance the health, performance, and lived experience of trainees.

13:15 – 13:30: Sex differences in sleep across a large cohort of military personnel

Bradley M Ritland [1], Jason L Judkins [1], Joseph R Kardouni [2], Stefan Pasiakos [1], Julianna M Jayne [1]

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[2]US Army Forces Command, USA

Purpose: Sleep is essential for optimal health and performance. Sleep issues, such as insufficient sleep and poor sleep quality, are common and well documented in military personnel. However, research comparing sleep between male and female soldiers remains sparse. The purpose of this study was to investigate sex differences in sleep metrics in a large cohort of military service members. **Methods:** Soldiers (n = 912, 26.6 ± 6.6 y; males= 735, 26.8 ± 6.6 y; females = 177, 25.7 ± 6.5 y) from the 2nd Infantry Division, Joint Base Lewis-McChord, WA, USA and 101st Airborne Division, Fort Campbell, KY, USA completed the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS). Independent samples t-test were performed to explore sex differences between PSQI and ESS scores. **Results:** For PSQI scores, the global sleep quality score (9.24 ± 3.60 *vs* 8.23 ± 3.81, $p = 0.005$), sleep latency (component 2) score (1.64 ± 0.98 *vs* 1.45 ± 0.81, $p = 0.014$), sleep disturbance (component 5) score (1.47 ± 0.66 *vs* 1.24 ± 0.64, $p < 0.001$), sleep medicine use (component 6) score (0.75 ± 1.17 *vs* 0.46 ± 0.96, $p = 0.002$), and daytime dysfunction (component 7) score (1.35 ± 1.00 *vs* 1.06 ± 1.01, $p < 0.001$) were all higher in females than males (indicating worse sleep quality / scores). Females also had higher ESS scores compared with males (9.44 ± 5.51 *vs* 8.37 ± 5.22, $p = 0.018$), indicating greater daytime sleepiness in females than in males. However, females reported longer sleep durations than males (6.04 ± 1.26 h *vs* 5.80 ± 1.27 h, $p = 0.027$). **Conclusions:** In this large cohort of military personnel, females reported poorer sleep quality and more daytime sleeping than males despite reporting slightly longer sleep durations (15 min / night). Results indicate that females may potentially be at increased risk for the negative health and performance implications associated with poor sleep quality and daytime sleepiness. **Military Impact:** Insufficient sleep (7 hours) and poor sleep quality continue to be an issue amongst military personnel. Future research should investigate the potential mechanisms behind the observed sex differences in sleep. Disclaimer: The views expressed herein are those of the authors and do not reflect the official policy of the Department of Army, Department of Defense, or the U.S. Government.

13:00 – 13:15: The relationship between sleep quality and poor health symptoms in US Navy Sailors

John Casachahua[1], Alice LaGoy[1], Andrew Kubala[1], Sean Deering[1], Luis Rosado[1], Jason Jameson[1], Matthew Peterson [1], Peter Roma [1], Dale Russell [2], Rachel Markwald [1]

[1]Naval Health Research Center, USA
[2]Naval Surface Force, USA

Purpose: Sleep can affect illness susceptibility, mental health, and recovery following physical injury. Monitoring and managing sleep are thus essential for maintaining warfighter health and readiness. This study explored the relationship between sleep characteristics and illness, and mental and physical health symptoms in a sample of US Navy Sailors. **Methods:** Two hundred and forty-nine Sailors (age: 31.5 ± 6.8 y; length of service: 10.5 ± 6.1 y; time aboard their respective ship: 14.9 ± 13.2 months) attached to one of four littoral combat ships wore a commercial wearable sleep monitoring device (Oura™ ring) during their fleet maintenance and completed monthly surveys assessing sleep, health, and behaviour. Sleep data 7 days prior to the survey assessment were used for analyses and surveys asked about 7-day recall of health. Independent variables included the Pittsburgh Sleep Quality Index, Patient-Reported Outcomes Measurement Information System, Sleep-Related Impairment scale, total sleep time (TST), and sleep efficiency (SE). Logistic regressions, with calculated odds ratios and 95% confidence intervals, were used to explore the relationship between individual sleep variables and prevalence of reporting at least one illness symptom (*e.g.*, cough, nausea), poor physical health (e.g., fatigue, pain), and poor mental health (*e.g.*, brain fog, anxiety). **Results:** Individuals with worse sleep quality were more likely to report illness (1.13 [1.01, 1.28]) and symptoms related to poor physical (1.20 [1.07, 1.38]) and mental (1.21 [1.06, 1.40]) health. Daytime impairment also predicted a greater likelihood of illness (1.07 [1.03, 1.12]) and symptoms of poor physical (1.09 [1.05, 1.15]) and mental (1.15 [1.09, 1.24]) health. An emerging trend suggests that TST and SE are related to illness (TST: 0.89 [0.59, 1.32]; SE: 0.97 [0.91, 1.03]), and symptoms of poor physical (TST: 0.95 [0.63, 1.42]; SE: 0.99 [0.93, 1.05]) and mental (TST: 0.76 [0.47, 1.23]; SE:

0.97 [0.91, 1.03]) health. A follow-up comparison of group means also suggests TST is more strongly associated with poor mental health outcomes than with poor physical health or illness. **Conclusions:** Overall, higher levels of fatigue and worse sleep were related to higher reported illness symptoms and symptoms of poor physical and mental health. Also, TST emerged as a potential predictor that was more strongly predictive of mental health problems than of physical health or illness. **Military Impact:** Sleep and fatigue are related to poor mental and physical health outcomes. Thus, monitoring sleep and fatigue should be an important component of military operations.

Oral Communication 20: Physical Performance

Thursday 14th September, 12:15 to 13:45

Room 2

Chair: Jace Drain, Defence Science and Technology Group, Australia

12:15 – 12:30: A 20 h military field training decreases the soldier's ability to perform casualty emergency evacuation

Jussi Mussalo [1], Jani P Vaara [1], Heikki Kyröläinen [2]

[1]Finnish Defence Forces, Finland
[2]University of Jyväskylä, Finland

Purpose: Casualty evacuation under enemy fire is one of the most physically demanding military tasks every soldier should be able to perform. Tests simulating casualty emergency evacuation (CEE) in an operational environment are influenced by anaerobic performance, lean body mass, and lower body strength (Mussalo et al., 2020, 5*th* ICSPP). The purpose of this study was to examine how the CEE test associates with physical fitness and body composition after 20 h military field training (MFT). **Methods:** 21 conscripts (16 men, 5 women) volunteered for measurements of anthropometrics (height 177 ± 10 cm, body mass 70.3 ± 9.3 kg, waist circumference 78.0 ± 5.5 cm), body composition, and physical fitness (12-min run test, Wingate test, standing long jump, 1-min sit-ups and push-ups, grip strength, isometric bench, and leg press). In the 20 h MFT, conscripts wore combat gear including a backpack (32.9 ± 1.4 kg), marched 38.5 km, and completed 11 tasks in groups. Conscripts' heart rate (HR) was continuously measured during MFT. Performance time (PT) of the CEE test was measured immediately after MFT. In the CEE test, conscripts wore combat gear (10.4 ± 1.3 kg) and dragged a doll wearing combat gear (80.2 kg). They dragged the doll 24 m while crawling (go round two cones, Z-pattern) and 20 m while upright (straightforward). Pearson correlation coefficient and regression analysis were used for statistical analyses. **Results:** During MFT, conscripts' mean HR was 117 ± 8 $b \cdot min^{-1}$ and peak HR was 174 ± 10 $b \cdot min^{-1}$, while energy expenditure was 5062 ± 865 kcal. PT was 126 ± 59 s, and strong correlations were found between PT and 12-min run test ($r = -0.69$, $p \leq 0.01$), muscle mass ($r = -0.61$, $p \leq 0.01$), and isometric leg press ($r = -0.54$, $p \leq 0.05$). PT correlated moderately with isometric bench press ($r = -0.49$, $p \leq 0.05$) and anaerobic capacity ($r = -0.47$, $p \leq 0.05$). 12-min run test ($ß = -0.61$, $p \leq 0.001$) and muscle mass ($ß = -0.55$, $p \leq 0.001$) explained variance in PT ($R2 = 0.78$, $p \leq 0.001$). **Conclusions:** After a strenuous 20 h MFT, good success in CEE requires most importantly good aerobic capacity and high lean body mass. These physical capabilities must be combined with high anaerobic performance and good muscle strength, especially, in the lower body. **Military Impact:** Military operations may acutely or chronically cause fatigue, which underlines the fact that physically demanding military duties, such as casualty evacuation, should also be able to perform in fatigued conditions. The present results emphasises that soldier's need the ability to recover during operations and to maintain sufficient strength.

12:30 – 12:45: Changes in physical training, physical performance, and injury after implementation of an age and gender-neutral military fitness test

Tyson Grier [1], Olivia Mahlmann [1], Michelle Canham-Chervak [1]

[1]Defense Centers for Public Health-Aberdeen, USA

Purpose: On 1 October 2020, the Army Combat Fitness Test (ACFT) replaced the 40-year-old Army Physical Fitness Test (APFT). The APFT measured muscular and aerobic endurance, while the ACFT measures five physical fitness components: muscular strength, muscular endurance, aerobic endurance, anaerobic endurance, and power. The purpose of this investigation was to evaluate changes in physical training, physical performance, and injury after the implementation of a pilot ACFT. **Methods:** Sixty-one battalions were selected to pilot the ACFT. At the time of the investigation, the ACFT was a gender and age-neutral test consisting of six events: deadlift (DL), standing power throw (SPT), hand release push-up (HRP), sprint-drag-carry (SDC), leg tuck (LT), and 2-mile run (TMR). A baseline survey was sent to 28,482 Soldiers collecting demographics, anthropometrics, physical training, physical performance, and health behaviours prior to the pilot. A follow-up survey was sent one year later to 35,380 Soldiers. Medical encounters for musculoskeletal injury were requested for 12 months prior to each survey. Chi-square tests were used to evaluate statistically significant differences in the frequencies between categorical variables. Paired t-tests and ANOVAs were used to assess statistically significant differences comparing the means among two or more groups. Adjusted odds ratios controlling for age and BMI were calculated to assess musculoskeletal injury risk associated with ACFT event performance. **Results:** Baseline and follow-up survey response rates were 18.2% and 10.0%, respectively, with 1,134 Soldiers (871 men, 263 women) completing both surveys. One of the largest changes observed in physical training was an increased number of minutes per week spent resistance training for men (+28.9% for unit and +24.2% for personal training) and women (+53.5% for unit and +38.5% for personal training). Men were 2.77 times more likely to pass the ACFT (75.6%) compared with women (27.2%). Soldiers with the highest body mass index (BMIs) had higher performance on the DL and SPT, while Soldiers with the lowest BMIs had higher performance on the LT and TMR. Musculoskeletal injury incidence increased from 40.8% to 47.6% after one year of the pilot ACFT for men and from 46.0% to 55.9% for women. For men, low performance on five of the ACFT events (DL, HRP, SDC, LT, TMR) was associated with a 1.31 to 1.55 times greater risk of a musculoskeletal injury compared to high event performance. For women, low performance on two of the ACFT (SDC, TMR) events was associated with a 1.91 to 2.17 times greater risk of a musculoskeletal injury compared to high event performance. **Conclusions:** Implementing a new physical fitness test, the ACFT, affected physical training behaviours, physical performance, and musculoskeletal injury incidence. **Military Impact:** Sex and body composition influence military physical fitness test performance. Soldiers will adapt their physical training program to meet the demands of a new physical fitness test.

12:45 – 13:00: Establishment of reference body composition values for healthy fit military men and women: new and improved physical readiness metrics

Karl Friedl [1], David Looney [1], Lyndsey Nindl [1], William Tharion [1], Adam Potter [1]

[1]U.S. Army Research Institute of Environmental Medicine

Purpose: Body fat and lean mass are two key components of body composition associated with military readiness. Relative body fat (%BF) is a stable indicator of physical activity and nutrition habits, providing a metric of recent months' fitness behaviours, while lean body mass (LBM) is

associated with physical strength, musculoskeletal injury risk, and trainability. Body size (e.g., body mass index) is wholly inadequate in the prediction of body composition, but reference ranges for the more direct measures (%BF and LBM) have not been established, especially for fit women and for fit ageing men and women. This study represents the first attempt to estimate ranges of %BF and LBM for fit military men and women. **Methods:** Body composition and fitness data were obtained from a convenience sample of 2,175 volunteer Marines (including 736 women) at three major bases. The U.S. Marine Corps (USMC) represents a unique culture of fitness, where physical readiness is a top priority regardless of age. Body composition was assessed by DXA scans, with individuals wearing USMC standard fitness training uniforms. Women provided negative urine pregnancy tests before testing. A subset included new 2nd Lieutenants, sampled from classes throughout a one-year period and analysed as representative young but physically mature (3rd decade) individuals. **Results:** Across all age groups, %BF was (mean ± SD) 21.9 ± 6.2 % and 30.1 ± 6.4 %, and LBM was 63.7 ± 8.0 kg and 44.9 ± 5.5 kg, for men and women. These data were broken down within four age groupings of 17 to 25, 26 to 35, 26 to 45, and ≥46 y; %BF was lower, and LBM was higher, than age-matched National Health and Nutrition Examination Survey (NHANES) values. For the subsample representing "ideal" (young but physically mature), %BF (mean ± SD, 5th and 95th percentiles) were 16.2 ± 4.1 (10.5, 24.7) % and 24.3 ± 4.5 (17.4, 31.9) %, and LBM was 67.8 ± 7.2 (56.8, 80.9) kg and 49.4 ± 5.3 (40.7, 57.0) kg for men (n = 174) and women (n = 70); these values were stable over a six-month training period. **Conclusions:** This sample of healthy fit men and women had lower %BF and higher LBM than age matched men and women from the US population based on NHANES data. The sample in this study would not be well represented by younger recruits with incomplete physical development or by specialised athletes. These data provide the first estimates of body composition of healthy active humans, with health behaviours more consistent with our ancestral persistence hunter biology. **Military Impact:** Practical and reliable direct assessment of %BF and LBM using science-based reference values will guide fitness and training habits and improve military readiness.

13:00 – 13:15: Are front length and chest breadth effective predictors of ergonomic fit of body armour systems?

Celeste E Coltman [1], Brooke R Brisbine [1], Richard H Molloy [2]

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[2]Defence Science and Technology Group, Australia

Purpose: Issuance of military body armour systems is commonly determined with sizing charts, using 2D torso measures such as front length (FL) and chest breadth (CB). However, it is unknown whether two-dimensional anthropometric dimensions are effective measures for sizing and subsequently fitting body armour. This study aimed to determine whether FL and CB can predict ergonomic fit of body armour. **Methods:** FL and CB were measured on 77 male and 31 female Australian soldiers (mean age: 23.6 ± 5.0 y; height range: 1.60 – 2.00 m; body mass range: 55.8 – 119.0 kg). Using FL and CB, soldiers were allocated one of five sizes of trial body armour system. Soldiers then performed a series of dynamic and occupationally relevant

tasks before rating the perceived interference of system length and system width on a Likert scale from 0 to 10. A linear regression determined whether measures of FL and CB (represented as a percentage of the overall length and width of the allocated trial body armour system) were effective predictors of length and width interference ratings. **Results:** FL (males: 35.3 ± 2.7 cm, females: 33.7 ± 2.0 cm) as a percentage of plate length (85 – 115%) did not significantly predict length interference scores (males: 5 / 10, females: 4 / 10) for males ($R^2 < 0.001$, $p = 0.845$) or females ($R^2 = 0.048$, $p = 0.234$). CB (males: 31.5 ± 2.1 cm, females: 28.9 ± 1.6 cm) as a percentage of plate width (112 – 142%) did not significantly predict width interference scores (males: 3.7 / 10, females: 2.2 / 10) for females ($R^2 = 0.001$, $p = 0.854$), but did predict width interference scores for males ($R^2 = 0.055$, $p = 0.041$). **Conclusions:** Except for chest breadth for males, which was able to predict just 5.5% of the variability in width interference scores, FL and CB were not found to be effective predictors of ergonomic fit based on the systems trialled. These results suggest that modifications to the trial systems are required and other variables—particularly three-dimensional anthropometry—should be considered when sizing soldiers into body armour. **Military Impact:** Body armour manufacturers and Defence organisations are encouraged to develop more robust sizing systems, which may in turn improve ergonomic fit for some soldiers within the range of existing body armour. Modifications to the current sizing suites may also be warranted based on a thorough examination of anthropometric dimensions that most closely relate to ergonomic fit.

13:15 – 13:30: Predictive value of modifiable and nonmodifiable characteristics on passing a military-based physical employment standard assessment in physically-active men and women

Evan Feigel [1], Adam J Sterczala [1], Kellen T Krajewski [1], Nicole Sekel [1], Mita Lovalekar [1], Kristen J Koltun [1], Shawn Flanagan [1], Chris Connaboy [1], Brian J Martin [1], Sophie L Wardle [2], Thomas J O'Leary [2], Julie P Greeves [2], Bradley C Nindl [1]

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Purpose: Women in ground close combat (GCC) roles may perform more poorly than men during occupational tasks, thus requiring understanding as to which modifiable (body composition, fitness) and nonmodifiable (age, sex, height) characteristics can predict passing the physical employment standard (PES) of criterion tasks encountered during GCC roles. Understanding these characteristics may inform pre-accession training programs to target these modifiable characteristics for improving occupational performance for women. Hence, we aimed to determine which modifiable and nonmodifiable characteristics predicted passing GCC-based PES assessments. **Methods:** 107 adults (46 women) participated. Dual-energy X-ray absorptiometry assessed percent body fat (%BF), regional and whole-body lean mass (LM, kg), and fat mass (FM, kg). Ratios of regional-to-whole-body LM were calculated ([regional / whole-body LM] × 100, %). Upper-body power was assessed by isokinetic dynamometer ($120^\circ \cdot s^{-1}$) averaged from both limbs ($W \cdot kg^{-1}$). Aerobic capacity (VO_{2max}, $ml \cdot kg^{-1} \cdot min^{-1}$) was assessed via Bruce protocol. Maximal strength was attained from one-repetition maximum (1RM) bench

press (kg), deadlift (kg), and back squat (kg). Lower-body power ($W \cdot kg^{-1}$) was determined by maximal squat jump (30% 1RM back squat) on dual force plates. PES assessment comprised the medicine ball chest throw (MBCT), casualty drag (CD), maximum single lift (MSL), water can carry (WCC), repeated lift and carry (RLC), and 2 km ruck march (2KRM) with British Army pass standard used. Multiple binomial logistic regression analysis determined the association between modifiable and nonmodifiable characteristics and passing tasks expressed as odds ratio (OR) adjusted for sex. Statistical significance was set α = 0.05. **Results:** Regional (OR = 1.01 – 11.65, p = 0.001 – 0.047) and whole-body LM (OR = 1.21 – 1.81, p =0.001 – 0.014), height (OR = 1.07 – 1.08, p = 0.006 – 0.048), 1RM bench press (OR = 1.04 – 1.45, p = 0.005 – 0.036), back squat (OR = 1.03 – 1.05, p = 0.004 – 0.038) deadlift (OR = 1.03, p = 0.007 – 0.014), % regional LM (OR: 1.04 – 4.48, p = 0.008 – 0.034), and upper-body power (OR = 1.01 – 1.03, p = 0.003 – 0.030) predicted passing the CD, WCC, MSL, and MBCT. Regional (OR = 0.15 – 0.85, p < 0.001) and whole-body FM (OR = 0.82 – 0.89, p < 0.001), %BF (OR = 0.77 – 0.81, p < 0.001), % regional LM (OR = 0.69 – 1.43, p = 0.015 – 0.017), and VO_{2max} (OR = 1.21 – 1.60, p < 0.001) predicted passing the 2KRM and RLC. Male sex predicted passing the CD (OR = 0.01, p < 0.001) and RLC (OR = 0.06, p < 0.001). **Conclusions:** Passing the lifting, dragging, carrying, and throwing tasks is associated with taller stature, greater regional and whole-body LM, greater strength and power, and male sex, whereas passing manual material handling and loaded marching tasks is associated with male sex, less FM, and higher aerobic capacities. **Military Impact:** Training these modifiable characteristics may improve occupational performance in women entering GCC roles.

13:30 – 13:45: Fitness assessment tests predict operational performance on standardised LEAP obstacle course

Lotte Linssen [1], Milène Catoire [1], Marloes Lugtenberg [2], Eric Noorlander [3], Kaj Gijsbertse [1]

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Purpose: It is important that military personnel have the physical capability to meet the demands of their operational tasks. Understanding the underlying physical attributes of a soldier's operational performance is essential for developing optimal training and selecting programs. Various studies have investigated which physical fitness components predict soldier operational performance. However, the specific measurement of operational performance varies and lacks standardisation. Recently, the Load Effect Assessment Program (LEAP) was developed as a NATO standardised assessment of the effects of clothing and equipment on soldiers' operational performance. Despite its potential, no study has yet used the LEAP to express operational performance and evaluate the underlying contribution of various fitness measures. Therefore, this study determined the ability of common fitness assessment tests on predicting operational performance using the LEAP obstacle course. **Methods:** Retrospective analysis on 33 male participants (age: 21 ± 2 years, BMI: 22.2 ± 2.6 $kg \cdot m^{-2}$) was conducted. Participants performed fitness assessment tests on day one, and operational performance

was assessed on a consecutive day (day two). Fitness measurements comprised: hand grip strength, pull-ups, vertical jump height, Illinois agility, sit and reach flexibility, 40-m sprint, 12-min endurance run and Y-balance test. LEAP comprised 10 obstacles: tunnel and hatch, sprint, stairs and ladders, agility run, casualty drag, windows, bounding rushes, low crawl, high and low walls. A multiple step-wise linear regression analysis determined which of the fitness assessment tests had a significant contribution to LEAP performance. **Results:** The final model significantly predicted 64% of the variability in LEAP performance ($F = 12.2$, $R^2 = 0.636$, $p < 0.001$). The four significant predictors in the model included: pull-ups ($ß = -1.32$, $p = 0.003$), sprint ($ß = 21.59$, $p = 0.003$), 12-min run ($ß = 0.10$, $p = 0.023$), and Y-balance ($ß = -0.72$, $p = 0.024$). **Conclusions:** This study demonstrates that operational performance assessed by the LEAP obstacle course is best predicted by upper-body strength, followed by both anaerobic and aerobic capacity, and lastly by balance / coordination. Handgrip strength, lower body strength, and agility did not significantly contribute to LEAP performance. **Military Impact:** Balance / coordination appears to be one of the important attributes of operational performance, however common military training and selection programs prioritise strength, speed, and endurance. Occupational instructors could re-evaluate current physical training and selection programs to ensure it supports the required physical needs of soldiers. By ensuring that soldiers get adequate physical training, the military can increase mission success and reduce the risk of injury.

Oral Communication 21: Epidemiology

Thursday 14th September, 12:15 to 13:45

Room 3

Chair: *Henriette Hasselstrøm, Danish Defence Medical Command, Denmark*

12:15 – 12:30: Prevalence of exertional heat illness risk factors in a healthy military population

Kyla Driver [1], Timothy Mesite [2], Emma Atkinson [2], Chris King [3], Peter Finch [2], Mark Buller [1]

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Purpose: Common assumed risk factors such as: acclimatisation status, previous / current illness, recent immunisations, and lack of sleep are often reported in individuals who have experienced an exertional heat illness (EHI). However, it is currently unclear whether there is a similar incidence of these factors in individuals who have been exposed to the same training environment but have not experienced EHI. In this study, we examined the prevalence of these EHI risk factors in warfighters participating in high-risk training events who did not experience an EHI. **Methods:** Risk factors were assessed using self-reported data from 2,595 participants (n = 2,351 men and n = 232 women, age: 22.5 ± 4.6 y, height: 1.76 ± 0.08 m, and body mass: 76.7 ± 10.8 kg) who engaged in high-risk training exercises such as runs, ruck marches, and land navigation at various training locations across the U.S. Army, Marines or Air Force. The current analysis excludes any participants who experienced an EHI during the events (n = 6). Each participant completed a demographic / previous EHI questionnaire, and an EHI risk factors questionnaire prior to the event. We calculated frequency of occurrence of risk factors among the population along with the mean and standard deviation of BMI. **Results:** From the demographic questionnaire, the group average BMI was 24.7 ± 2.3 $kg \cdot m^{-2}$ (using self-reported height and body mass) and 2.85% had had a previous EHI. From the EHI risk factors questionnaire, participants reported 8.5% had 4 hours of sleep the night prior, 42.7% had between 4 and 6 hours of sleep, 5.6% were using supplements at the time, 4.8% confirmed having a prescription, 12.8% reported feeling unwell that day, 7.4% stated they had been ill or seen a physician in the last 60 days and 5.9% had an immunisation within the last 30 days. **Conclusions:** Group average BMI was lower than that reported by Giersch et al for at risk individuals (Giersch et al., 2023, *Am J Physiol Regul Integr Comp Physiol*, 324(1), R15-R19). Our group shows a small incidence of previous EHI but over 50% of individuals reported less than 6 hours of sleep. Over 10% of individuals reported feeling unwell on exercise day, and use of supplements, use of prescriptions, or recent immunisation all show an incidence of ~5%. These incident rates suggest that care should be taken when identifying risk factors from EHI cases alone. **Military Impact:** Understanding true possible EHI risk factors among individuals helps trainers and medical personnel stay informed on the safety of the warfighter in training and operations. Disclaimer: The opinions contained herein are the private views of the author(s) and are not to reflect the views of the US Army.

12:30 – 12:45: Applications of the Taxonomy of Injuries injury definition and standardised medical encounter reporting

Anna Schuh-Renner [1], Veronique D Hauschild [1], Ashleigh K McCabe [2], Bruce H Jones [1], Michelle Canham-Chervak [1]

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Purpose: Injuries are the leading cause of medical encounters and lost workdays among all U.S. military services. The U.S. Army Public Health Center's Taxonomy of Injuries, first published in 2017, introduced a comprehensive injury definition; identified diagnosis codes fitting this definition from the International Classification of Diseases, Tenth Edition, Clinical Modification (ICD-10-CM); and established a succinct reporting format to characterise population-level injury data. This presentation describes current applications of the Taxonomy. Methods: The Taxonomy defines injury as bodily damage caused by instantaneous or gradual transfer of an external mechanical, thermal, chemical, electrical, or radiological energy. Standardised categories for external energy type, injury type, and injured body area were applied to each ICD-10-CM injury diagnosis. Mechanical energy injuries were further differentiated as resulting from either a single high force (acute trauma) or repetitive low force cumulative microtraumas (overuse). Annual reviews ensure ICD-10-CM code updates released by the World Health Organization and the Centers for Disease Control and Prevention are documented in Taxonomy materials maintained online. A modified incidence rule was applied to better accommodate the increased number of injury diagnosis codes compared to previous ICD versions. The Taxonomy is routinely applied to medical encounter data for the U.S. Armed Forces. **Results:** The Taxonomy of Injuries has been used to report annual U.S. Army injury data for 6 years, as well as to summarise injury data for all U.S. military Services, allowing visualisation and comparison of the leading categories of energy transfer resulting in injuries. These applications have demonstrated that most injuries among military members are consistently due to mechanical energy, primarily cumulative micro-traumatic musculoskeletal overuse (~70%). The Taxonomy injury definition was captured in 2022 U.S. Department of Defense policy. The U.S. National Center for Health Statistics has recognised the Taxonomy, and at least 21 organizations from 3 countries have expressed interest in utilising the Taxonomy for their own injury surveillance and reporting. **Conclusions:** The Taxonomy of Injuries is a transparently documented approach for presenting injury epidemiological data that is reviewed annually to ensure methodological quality. As it becomes more widely recognised, this taxonomic structure allows for more comparable injury surveillance reporting and identification of the most important injury problems within the monitored populations. If desired, the Taxonomy allows investigators to focus analyses on specific subsets of injury diagnoses. **Military Impact:** Comprehensive injury surveillance quantifies the magnitude of injuries resulting from various categories of energy transfer and informs strategic injury prevention planning.

12:45 – 13:00: The prevalence of Medial Tibial Stress Syndrome in the British Armed Forces: a secondary data analysis based on data from the Armed Forces medical electronic notes system

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[3]HQ Army Recruit Initial Training Command, UK

Purpose: Medial Tibial Stress Syndrome (MTSS) is an exercise induced leg pain often experienced in military service personnel due to the physical demands of their role. Symptoms can prevent service personnel from passing fitness tests, completing military duties, being promoted, and in some cases, can lead to medical discharge. The operational and financial cost of MTSS to the military is likely to be high, due to the above factors, and associated medical and rehabilitation costs. No large-scale studies have investigated the extent to which MTSS impacts service personnel. We aimed to determine the prevalence of MTSS across the British Armed forces and demographics of those with the syndrome. **Methods:** A retrospective cross-sectional study design examined secondary data from electronic medical records between 1st January 2013 and 1st January 2019. Records of all military service personnel diagnosed with MTSS were used to extract demographic information and calculate prevalence (% with MTSS). Recruits, as a high-risk population, were reported separately. Results: The prevalence of MTSS across the Armed Forces declined from 2.23% to 1.60% between 2013 and 2018 (inclusive). In Army training centres, the prevalence was significantly higher than across the Armed Forces, remaining relatively stable between 2013 (3.77%) and 2018 (3.46%). A greater percentage of female service personnel had MTSS (decreasing from 2.62% to 2.14%), compared with men (2.19% to 1.57%). The mean age for diagnosis of MTSS was 25 years and the mean length of service when diagnosed was c.5 years. The mean number of contacts with a health professional for MTSS was 11.08 with 27% of service personnel only having one contact. The mean number of days receiving healthcare for MTSS was 302.32 days. Two percent of all service personnel with MTSS were medically discharged with a lower limb injury as either the principle or contributory reason for discharge. **Conclusions:** MTSS prevalence has reduced across the Armed Forces, however remained stable in Army training centres. Recruits often experience a rapid increase in training volume and load during training increasing the risk of overuse injuries. Female service personnel continue to be at an increased risk compared with males. It has been suggested that women may be more at risk due to altered biomechanics or hormones, influencing tibial bone density. **Military Impact:** Strategies to reduce MTSS should focus on reducing the risk in training units and explore further how to protect female service personnel from developing the condition.

13:00 – 13:15: Risks associated with injury in soldiers following knee surgeries at on-post versus off-post surgical facilities

Benjamin Adams [1], Kathryn M Taylor [1], Richard Westrick [1]

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Purpose: The purpose of this study was to identify risk factors for sustaining a musculoskeletal injury (MSKI) in Soldiers following knee surgery. We also evaluated if there were differences in outcomes for Soldiers who had knee surgery at a military treatment facility (MTF) compared with a non-MTF. **Methods:** Data were extracted from the Soldier Performance, Health, and Readiness Database. Active-duty Soldiers were included in the study if they had knee surgery from 1st January 2017 to 1st January 2020. Surgical procedures included repair of the articular cartilage, meniscus, ligament or bursa, multi-ligament repair, patella, or tendons of the knee joint. Multivariate logistic regression was used to estimate post-surgical MSKI risk factors. Covariates included in the model were: age, body mass index, race, sex, tobacco use, previous injury / surgical history, military occupation, rank, years of service, and treatment facility (MTF vs non-MTF). Data cleaning and analyses were completed using R statistical software (v4.2.0; R Core Team). **Results:** A total of 7,595 Soldiers (88% men, 32% with combat-related occupations) underwent knee surgery within the observation window. Nearly 71% sustained a subsequent lower extremity or lumbar spine injury within 4 years of surgery. Significant predictors of post-operative MSKI included: history of pre-operative injury (OR [95% CI] = 1.44 [1.30 – 1.60]), female sex (1.37 [1.10 – 1.70]), Black race (1.25 [1.10 – 1.40]), and treatment at a non-MTF (1.15, [1.02 – 1.30]). Approximately one-third (34%) of surgeries were performed at a non-MTF; Soldiers receiving surgery at a non-MTF were older by a mean of 3.7 y and a higher percentage were officers (28%) compared with those who underwent surgery at a MTF (18%). Surgery at a non-MTF was associated with a higher post-surgery MSKI frequency (73% vs 69%), and earlier post-surgical injury (mean 6.7 months) compared to surgical procedures performed at an MTF (mean 7.6 months). **Conclusions:** Most Soldiers sustained a new injury after knee surgery. Injury history, sex, race, and surgery facility significantly predicted post-operative MSKI. Undergoing an orthopaedic knee surgical procedure at an MTF may be favourable to surgeries at a non-MTF due to lower injury frequency and longer time to post-surgery MSKI. **Military Impact:** With the high volume of knee surgeries in the military, lower re-injury rates and favourable post-surgical timelines associated with MTF surgeries may have implications for military health system policymakers when allocating resources associated with orthopaedic surgical care.

13:15 – 13:30: The effect of aerobic activity and combat exposure on new-onset mental health diagnoses after deployment to a combat zone

Diane Williams [1], James C Yea [2]

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[2]Leidos, Inc., USA

Purpose: The goal of this study was to determine the predictive relationship of prospectively gathered pre-accession factors and combat exposures on mental health diagnoses of US active-duty service members after initial deployment to a combat zone. Development of a mental health disorder may render service members unable to perform their duties and may lead to separation from service. **Methods:** Using a cohort design, pre-accession characteristics and combat exposures of 39,383 US service members were compared according to whether they subsequently received a mental health diagnosis. Participants were restricted to those who had an initial deployment to a combat zone between 2005 and 2008, and who had not received a mental health diagnosis before deployment. Factors associated with increased and decreased resilience to mental health diagnoses were determined using logistic regression. **Results:** In the fully adjusted logistic elationnn model, factors associated with increased resilience for mental health diagnoses included a history of engaging in aerobic activity, graduating high school, and having above average vocational aptitude. Factors associated with decreased resilience were having experienced childhood adversities such as separation from parents, household instability, childhood poverty, parental mental health problems, exposure to potentially traumatic events, and Adverse Childhood Experiences. Other factors associated with decreased resilience included the behavioural factors of engaging in problematic conduct (minor forms of delinquency), smoking tobacco, and the health factor of having experienced greater levels of pain. Experiencing combat exposures also was associated with decreased resilience in a dose-response manner. **Conclusions:** Along with combat exposures, prospectively gathered pre-accession factors were predictive of new-onset mental health problems after initial deployment to a combat zone. Exercise, vocational aptitude, and education were associated with resilience to adverse effects of combat deployment on mental health, while exposure to childhood adversity, a history of participation in minor forms of delinquency, smoking, experiencing bodily pain, and combat exposures were associated with decreased resilience. Pre-accession mental health problems were not predictive of subsequent mental health diagnoses—illustrating the challenges of predicting mental health diagnoses during military service. These research results support the importance of engaging in aerobic activity in maintaining mental health after deployment to a combat zone. **Military Impact:** This information can be used to support vulnerable service members, as well as by clinical providers who treat adversely affected warfighters.

13:30 – 13:45: Half a decade of heat injuries in the Israel Defense Forces (IDF): lessons learned and future directions

Inbal Akavian [1], Alexandra Rabotin [2], Shiraz Peretz [3], Daniel S Moran [4], Yoram Epstein [5], Itay Ketko [1]

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[4]Ariel University, Israel
[5]Tel Aviv University, Israel

Purpose: In the Israel Defense Forces, service members who experience exertional heat illness

(EHI) are required to undergo a medical evaluation at the Institute of Military Physiology prior to return to duty. This study aimed to characterize and review the risk factors and clinical presentation of patients who suffered EHI. **Methods:** The records of 270 young soldiers (aged 18-21 y) diagnosed with EHI between 2017-2021 were analysed. T-tests and Mann-Whitney tests were used to compare symptoms of exertional heat stroke (EHS) with the other forms of EHI. **Results:** From the total analysed cohort, 127 soldiers were classified as EHS, and 146 who suffered other forms of EHI. The most common risk factors for heat stroke or non-EHS injury were similar: activity under excessive heat load (25-30%), dehydration (15-20%), underlying illness (20-30%), and sleep deprivation (25-30%). Late recognition of symptoms was more prevalent in EHS patients ($p = 0.009$). In contrast, underlying illness was more prevalent in non-EHS injury patients ($p = 0.035$). The clinical presentation of EHS and non-EHS injury patients was similar (the most prominent symptoms encountered were confusion, collapse, and dizziness) except for amnesia, which was almost 10% higher among EHS patients ($p = 0.006$). Laboratory tests in the emergency department indicated that EHS patients were likelier to have higher leucocytosis, abnormal creatinine, CPK, liver enzymes, and calcium and phosphorus levels ($p < 0.05$). **Conclusions:** In general, EHS and non-EHS injuries cannot be differentiated in the field based solely on clinical presentation. However, this study identified differences in predisposal risk factors and post-event laboratory test results for EHS. **Military Impact:** Our registry can improve awareness and optimise the management of EHI cases in the field by medical teams and commanders. It may also be used to extract valuable lessons and be utilised in defining cut-off points and developing decision-making tools as part of the return to duty process. Measuring core temperature on site in a collapsed active soldier will assist in EHS diagnosis.

Posters 3: Physical Training

Thursday 14th September, 12:15 to 13:45

Board 1: The concept of military endurance training in the Danish Defence

Jesper Gronemann Wendell [1], Aksel Nielsen [1], Henriette Hasselstrøm [1], Frank Thøgersen [1]

[1]Center for Military Physical Training, Denmark

Purpose: Until recently the Danish Defence did not have a specified concept for endurance training. Formerly, the physical trainers autonomously decided how to perform endurance training, which entailed both inappropriate training variation and inefficiencies with resources when educating new soldiers. The aim of the Danish Military Endurance Training Concept is to "Improve the ability to work with moderate to very high intensity over a period from a few seconds to several hours with both continuous and intermittent work". The "Danish Military Endurance" is defined as "The ability to resist fatigue and the will to persist, when the physical load and mental effort are increased because of physical demands of an exhausting intensity and duration". The purpose of this study was to develop a time efficient endurance training concept that would standardize the endurance training for the entire Danish Defence. **Methods:** In the research and development process, the concept has been evaluated and tested through a trial-and-error approach in several units, at officer schools, and at training courses in the Danish Defence. The concept is based on scientific empiricism, civilian best practice, and years of experience with physical training in the Danish Defence. **Results:** The Danish Military Endurance Training Concept consists of six training sessions: 1) easy, 2) moderate, 3) hard, 4) VO_{2max}, 5) speed endurance, and 6) sprint. The training sessions are designed to improve VO_{2max}, %-VO_{2max}, running economy, and anaerobic capacity. A training session provides guidelines on duration, intensity, and recovery, but also tools to handle the mental aspect of endurance performance. In addition, a training session considers individual physical differences and can be performed both individually and as unit related training. Lessons learned throughout the development process were that a number of factors play a decisive role in making the endurance concept work in a military context: training time, unit size, simplicity, individualisation, specificity, injury prevention, number and competence of physical trainers, training conditions during missions, ships etc., training planning and programming, and integration with strength and mobility training. **Conclusions:** A time efficient endurance training concept was developed. A training concept that may be used both individually and as unit related training. By developing the Danish Military Training Concept, the physical trainers use fewer resources on educating new soldiers and on preparing endurance training sessions. **Military Impact:** The experiences and insights gained from the design process can easily be extended to other countries that wishes to develop a military endurance training concept.

Board 2: The influence of a field-based training on anthropometric measures among Brazilian cadets

Willian C Botta [1], José M Magraner [1], Fábio A Campos [1], João P Borin [2]

[1]Brazilian Air Force, Brazil
[2]University of Campinas, Brazil

Purpose: Throughout their training period in the military school, the Brazilian Air Force cadets must take part in several field-based and survival activities to be prepared to perform their professional duties in the future. In one of these exercises, referred to as Leadership Skills Camp (LSC), the cadets are divided into combat groups comprised of 12 people, and they must deal with challenging scenarios over 72 hours, taking decisions under physical and psychological stress. This study aimed to investigate the response of the anthropometric profile of Brazilian cadets submitted to three days of training in the LSC. **Methods:** The sample was comprised of 155 healthy volunteer cadets (14 women and 141 men; aged 21.3 ± 1.2 y). The participants were submitted to the same evaluation battery at two distinct times: the first data collection occurred two days before the LSC training, and the second took part at the end of such training (30 min after the last scheduled activity). The evaluation batteries were comprised of the following measurements: body mass, height, three skinfold thickness, and body fat percentage. The body fat percentage was calculated using the protocol of Guedes & Guedes (1991) and Siri (1961), and the same four evaluators worked in both collections. Data distributions were analysed using the Shapiro-Wilk test, and the variables were compared using paired Student's t-test. The significance level was set at $p < 0.05$. **Results:** Significant differences were identified between the two collections in body mass (−1.3 kg; $p < 0.01$), the sum of skinfold thickness (−7.52 mm; $p < 0.01$), and body fat percentage (−2.24 %; $p < 0.01$). However, the height measurements were not different. **Conclusions:** This study identified that, during three days of LSC training, there was a significant decrease in body mass, the sum of skinfold thickness, and body fat percentage among the participants. Considering the high physical demands, the reduction in caloric intake, and sleep restrictions caused by this training, such a decrease in the variables was expected, and further studies are suggested to better understand these changes. **Military Impact:** Reliable physical monitoring is essential to enhance combat readiness.

Board 3: Heart rate variability assessment of land navigation and load carriage in specialist police selection training

Colin Tomes [1], Elisa F D Canetti [1], Ben Schram [1], Robin Orr [1]

[1]Bond University Tactical Research Unit, Australia

Purpose: In Australia, specialist police personnel assigned to police tactical groups (PTG) are often tasked with atypical or paramilitary duties. Consequently, PTG selection courses must also be highly rigorous. Attrition is often high and candidate failure/withdrawal is typical, particularly during load carriage (LC) tasks. Hence, health and performance monitoring may be beneficial. Heart Rate Variability (HRV) is one holistic measure obtainable through wearable technology monitoring. HRV is a valid measure of holistic stress response and is pragmatic in austere field environments where collecting other stress bio signals may be impractical. However, research on wearable derived HRV application in PTG selection remains limited. Therefore, this study aimed to 1) generate HRV profiles of candidates during challenging LC tasks, 2) summarize data in a format accessible by end-users, and 3) determine the relationnship between HRV and attrition. **Methods:** An initial cohort of 18 male law enforcement officers completed a 1-day assessment. Of those, six males progressed to an additional two-day selection course, on which

this study is focused. This two-day selection course consisted of additional physical challenges (LC, swimming, stores transportation, circuit training), but also essential PTG occupational task assessments (firearms safety and manipulation, threat de-escalation). Specifically for this study, HRV response during 13 hours of continuous LC was of primary interest to obtain an HRV profile and determine if withinevent HRV predicted attrition. Candidates were supplied EQ02+ LifeMonitors (Equivital™, Cambridge, UK), collecting 2-lead ECGs. HRV was defined as the percentage of R-R intervals varying by at least 50 ms (pRR50%) as epidemiological studies and previous research in specialist police report pRR50%. Data were summarized in a heat map of 153 consecutive 5-minute HRV measurements. Heat map shaded regions were defined as < 6.25% (red), > 6.25% but within one standard deviation (SD) of their own 13-hour pRR50 value (yellow), or > 1SD of that value (green). Logistic regression analysis was used to predict attrition from heat map count data. **Results:** Three candidates withdrew. The regression model was statistically significant (χ^2 (6) = 5.545, p = 0.019), correctly identifying 66.67% of candidates that passed and 100% of candidates that withdrew. Conclusions: HRV data may provide insight for PTG stakeholders monitoring attrition risk. Conversely, exceptional performers, or those who remain effective despite potential overstress can also be identified. **Military Impact:** Previous HRV research has combined specialist police and military cohorts. This novel approach to HRV assessment may translate across tactical organisations seeking additional selection process supports.

Board 4: Motivation for physical training among Danish military personnel: a cross sectional survey

Frank Thøgersen [1], Henriette Hasselstrøm [1]

[1]Centre for Military Physical Training, Denmark

Purpose: Physical training (PT) is an inherently non-intrinsic activity for most people. This study aimed to investigate how military physical training (MPT) participation is affected by organisational factors such as fitness tests, deployment recommendations, and restrictions of personal autonomy within training. **Methods:** Using a cross-sectional study design and qualitative analysis, the relationship between Danish military employee's participation in MPT and the motivational structures that surrounds participation were investigated. The qualitative data were summarised in tables and graphs and visually inspected. Wilcoxon tests were used in cross-analysis of variables. The survey asked questions on topics such as training habits, preferences, motivation, participation, perceived relevance of MPT, importance of operational physical readiness, impact of physical test on motivation, and barriers to training. Data were cross analysed with demographics including measures of thriving and self-rated physical fitness. Results were compared between demographics categories. **Results:** 17% (n = 3650) of military employees responded to the survey. 52% of respondents with military contracts completed MPT for 1 – 4 $h \cdot week^{-1}$ while 11% trained > 4 $h \cdot week^{-1}$. There was a strong relationship between time participating in MPT and both age and military rank. Cross analysis revealed that participation was mainly driven by perceived relevance of MPT to operative performance; individual physical recommendation standards and perceived efficacy of MPT correlated with

more hours of MPT participation. Fitness tests had negative effects on training motivation in those respondents who did not see any relevance of MPT to operative performance. The main perceived barriers to training MPT was insufficient time for training and the responsibility was seen as shared between leader and employee. **Conclusions:** The training motivation and MPT participation was generally high in the Danish Defence. The psychological needs for autonomy or competence in service personnel did not seem to be negatively impacted by MTP, fitness test, or physical standards. If current Danish physical recommendations were organisationally transformed into unconditional requirements for operational deployment, only those with very low self-rated physical fitness would perceive a negative impact on training motivation. **Military Impact:** To secure a high standard for physical readiness in military personnel, results from the Danish defence indicate that armed forces should emphasise the operational relevance and efficacy of their MPT concepts to their personnel, physical training instructors, and leaders. This emphasis could possibly be achieved either during their training, education, or through strategic mass communication.

Board 5: The effects of survival-run training on creativity and physical adaptivity

Kaj Gijsbertse [1], Milène Catoire [1], Marloes Lugtenberg [2], Eric Noorlander [3], Lotte Linssen [1]

[1]The Netherlands Organization for Applied Scientific Research, The Netherlands
[2]Radboud University, The Netherlands
[3]Royal Netherlands Army, The Netherlands

Purpose: Physical fitness is a critical component of military operations, and soldiers must maintain a high level of fitness to perform their duties effectively. Changes in warfare tactics and strategies influence how soldiers fight and operate. These constant changes of operation have led to an increased emphasis on mobility, flexibility, and adaptability. However, current physical training programs in many militaries are based on traditional obstacle courses and activities that were developed decades ago and may not adequately address the specific physical demands of modern military operations. There is a need to modernise and improve physical training to prepare soldiers for the demands of modern conflicts. In this context, this study explores the effectiveness of a survival-run obstacle course to increase soldiers' motor creativity and physical adaptivity. **Methods:** Twenty-two male (age: 22 ± 3.7 y, height: 1.81 ± 0.05 m, body mass: 81.4 ± 10.9 kg) non-commissioned officers cadets participated in the evaluation of the survival-run course as part of their regular physical training. The participants were divided into two groups: one group followed the regular physical training program included in the curriculum three times a week (nine participants), while the other group replaced some of these training sessions (1-2 per week) with training on the survival-run course (thirteen participants). The intervention period lasted eight weeks. The following outcome measures were assessed before and after the intervention period: strength, speed, coordination, flexibility, endurance, motor creativity, and operational performance – LEAP obstacle course. In addition, the LEAP obstacle course was modified into a 'LEAP-adapt' during the post-measurement to assess the physical adaptivity of the participants. **Results:** No significant differences in changes in the basic movement skills strength, speed, coordination and flexibility were found between the groups. Endurance of the intervention group was slightly less improved on an endurance run compared with the regular training program (−36.3 ± 44.0 s and −8.1 ± 25.8 s, respectively, $p = 0.085$). No significant changes in operational performance (LEAP, s) nor physical adaptivity (LEAP-adapt, s) were found. Motor creativity was increased in terms of DDT-fluency (defined as the number of unique movements) for the intervention group compared with the control group (2.5 ± 3.2 and −1.4 ± 3.5, respectively, $p = 0.012$). **Conclusions:** Training on the survival-run obstacle course improves soldiers' motor creativity but does not result in larger physical adaptivity compared with regular training on traditional NATO obstacle course. **Military Impact:** By improving physical training programs, militaries can better prepare soldiers to operate effectively in modern conflicts and ensure the success and safety of military operations.

Board 6: Designing human performance tools for US Army Holistic Health and Fitness technology enablement

Teo Balbach [1], Jake Repanshek [2], Kevin Dawidowicz [1]

[1]CoachMePlus, USA
[2]TIAG, USA

Purpose: The United States Army's Holistic Health and Fitness (H2F) programme is the Army's primary investment in soldier readiness and lethality, optimal physical and non-physical performance, reduced injury rates, improved rehabilitation after injury, and increased overall effectiveness of the total Army. H2F focuses on five complementary domains of soldier wellness: physical, sleep, nutrition, mental, and spiritual. The collection of human performance data and the ability to interact with soldiers dynamically are key components to the success of the H2F program. This study sought to demonstrate the effectiveness of a commercial athlete management system (CoachMePlus) to support the H2F program through technology enablement. **Methods:** The CoachMePlus athlete management system (AMS) is an enterprise-grade human performance data collection and management platform featuring capabilities such as a workout builder, nutrition tracker, customizable forms and surveys, activity planning, group and individual messaging, an algorithm engine, dashboards and reports, content libraries, etc. The platform also supports integrations with over 60 commercial wearables and other hardware such as scales and body composition measurement devices. As part of the H2F Management System (H2FMS) study, the CoachMePlus platform was deployed sequentially to three disparate Army units for a period of two months each, during which time soldiers and practitioners used the platform and associated mobile apps to enable local H2F-oriented programming and data collection. Soldiers were given the ability to opt-in to integrating personal wearable device data from supported platforms such as Garmin, Fitbit, and Apple HealthKit. Data collected included step counts, sleep quality, mindfulness data, etc. Each pilot location presented a distinct use case in terms of allotted staff and resources, as well as soldier availability. Engagement was tracked through unique and repeat logins as well as virtual interactions with content and practitioners across all H2F domains. **Results:** The pilot demonstrated meaningful soldier participation and engagement. CoachMePlus registered 2,300 individual soldier participants and recorded over 17,500 logins across the life of the pilot period. On average, participants logged into the app at least twice per week, and at one location almost three times per week. 70% of registered users logged into the app three or more times, indicative of the "stickiness" of the platform. Over 70,000 workout sets were tracked, and over 150,000 wearable data points were automatically captured from personal wearable devices spanning Apple, Whoop, Fitbit, and Garmin. Anecdotally, the team received encouraging feedback from participating H2FMS stakeholders, particularly practitioners in non-fitness domains who have traditionally not had access to technology to enable interaction with soldiers. The ability of the CoachMePlus platform to support content distribution, in-app communication, and specialized capabilities such as the nutrition tracker was lauded as highly beneficial to H2F practitioners at large. **Conclusions:** The CoachMePlus AMS stimulated meaningful soldier participation and facilitated engagement and data collection across all domains. The technology offers promise as a tool to amplify and enable soldier wellbeing initiatives. **Military Impact:** Military organizations should further explore and invest in the use of AMS technologies to engage with warfighters and promote holistic health and wellbeing initiatives.

Board 7: The development of quantitative performance metrics for squads entering and clearing a room (Battle Drill 6)

Clifford Hancock [1], Meghan O'Donovan [1], Greg Goodwin [1]

[1]US Army DEVCOM Soldier Center, USA

Purpose: Squad performance for Battle Drill 6 (BD6), enter and clear a room, is typically assessed by observer controllers (Ocs) who view and subjectively rate squads based upon standard task steps outlined within military doctrine. The purpose of this study was to utilize instrumentation to supplement Ocs observations with squad-level, quantitative performance metrics and to determine if these novel metrics could statistically differentiate between squads based on their battle drill performance and proficiency. **Methods:** Fifteen US Army infantry squads (N = 120 male soldiers) completed BD6 within a motion capture instrumented shoot house consisting of an exterior entryway, a corridor, and three closed-door rooms. Motion capture analysis was focused on a single room which contained an armed enemy combatant. Squads completed three trials on three consecutive days, and the enemy location was randomized for each iteration. Performance metrics were post-processed using custom algorithms to analyse the motion of each soldier's torso, helmet, and weapon. ANOVAs ($\alpha = 0.05$) tested the main effects of squad for each metric, and simple linear regressions determined if relationships existed with Ocs subjective scores. Mean ± standard deviation values across all squads are provided below for each performance metric. **Results:** Mean room scan rate, calculated using estimated weapon aim points, was significantly different between squads (15.54 ± 5.90 %·s^{-1}, $p = 0.045$). Mean duration in the fatal funnel, calculated as the time spent within fatal funnel bounds, mean duration until on target, calculated as time elapsed until a weapon aim point contacted the enemy, and hugging-wall distance, calculated as the mean squad distance to the nearest interior wall, also varied between squads (2.70 ± 1.37s, $p = 0.049$; 2.39 ± 2.72s, $p = 0.011$; 0.46 ± 0.15 m, $p < 0.001$). Squad duration in the fatal funnel significantly correlated with the overall

OC score (R = 0.12, p = 0.02), squad control score (R^2 = 0.16, p = 0.01), squad simplicity score (R^2 = 0.28, p < 0.001), and the squad supporting behaviour score (R^2 = 0.16, p = 0.01). The squad speed score was significantly correlated with the average distance between Soldiers while crossing the room threshold (R^2 = 0.12, p = 0.02) and the duration until on target (R^2 = 0.14, p = 0.01). Findings show Ocs provided higher performance scores to squads who quickly traversed the fatal funnel, maintained tight spacing, and immediately aimed their weapons on target. **Conclusions:** This study identified performance metrics that differentiate squads of varying proficiencies and correlate with subjective ratings by Ocs. Systems that can quantify these types of metrics could assist Ocs in providing more reliable and quantitative feedback to enhance squad training. **Military Impact:** The addition of objective performance metrics to typical after-action reviews will improve training efficiency and efficacy.

Board 8: Outcomes following musculoskeletal injury during Army basic training

Andrew J Roberts [1], Shaun Chapman [1], Henry Ogden [1], Alex J Rawcliffe [1]

[1]Army Recruit Health and Performance Research, UK

Purpose: There is a high prevalence of musculoskeletal injuries (MSKIs) during basic training that can have direct negative consequences such as medical discharges (MDs), lost training days and re-squadding. MSKIs may also indirectly contribute to other types of attrition. For example, a lack of physical robustness and lower mood states, that may be related to injury, have been reported as contributing to voluntary discharge. Our data describe the prevalence of medical and non-medical discharges following injury across British Army basic training. **Methods:** A 2-year retrospective analysis of the Army Recruiting and Initial Training Command MSKI database was undertaken. MSKI data were descriptively analysed for the training years: 2020/2021 and 2021/2022 (1st April to 31st March). MSKI data were collected from Primary Care Rehabilitation Facilities at British Army training units, and training outcome data from the management system. **Results:** Following an MSKI, 74% of 1805 patients were returned to training or entered reconditioning. The calf/shin (27% discharged), spine (26%) and shoulder (24%) were the three locations with the worst prognosis for training outcome, whilst the wrist/hand (6%) and foot (6%) had the best prognosis. Injuries to nerves (33% discharged), muscle (28%) and bone (27%) had the worst prognosis of those tissues injured. MSKI-associated MDs declined from 4.4% for men in 2013/14 and 5.5% for women in 2012/13, to 0.4% for men and 0.7% for women in 2020/21. MSKI-associated MDs also rebounded above 2019/20 pre COVID-19 records (1.0% men; 1.8% women) during 2021/22 (1.3% men; 2.1% women) following the overall MSKI pattern with the majority being lower limb MSKIs. **Conclusions:** While nerve injuries had the worst prognosis, they also have low prevalence. Muscle and bone MSKIs and injuries to the calf/shin both have either high prevalence, poor outcomes, or both. While the prevalence of specific diagnoses is not yet known, current efforts should be focused on reducing or improving the outcome of injuries to these regions & tissues. **Military Impact:** Strategies to reduce the impact of MSKIs should focus on reducing the risk, severity and improving treatment of lower limb overuse MSKIs, particularly those at the calf/shin with the biggest gains to be made by targeting muscle and bone injuries.

Posters 3: Nutrition and Metabolism

Thursday 14th September, 12:15 to 13:45

Board 9: The Future Defence Deployed Nutrition Programme: a pilot study to assess the utility of a new self-sustaining rapid insertion ration during a 7-day military field exercise

Daniel Rowland [1], Joanne L Fallowfield [1], Jason Tooley [2], Trish Davey [1], Joseph Hogan [1], Lana Richards [1], Rob Child [3]

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Purpose: Operational demands for very-high readiness Forces require personnel to self-sustain, at reach, for extended periods. To support these requirements, the UK's Future Defence Deployed Nutrition Programme developed a smaller (7 L volume), lighter (8 kg mass), more nutrient-dense Rapid Insertion Ration (RIR), to sustain personnel for seven days of operational activity. This pilot study compared the acceptability and physical performance benefits of the RIR (daily provision: 3916 kcal; 382 g carbohydrate; 119 g protein; 204 g fat) with 8 kg of the in-service Operational Ration Pack (daily provision: 2715 kcal; 307 g carbohydrate; 89 g protein; 116 g fat) during a 7-day field exercise. **Methods:** 24 male Royal Marines Commandos completed a 7-day field exercise, where participants consumed either the Operational Ration Pack ($n = 12$; Control) or RIR ($n = 12$). Groups were matched for physical characteristics and aerobic fitness. Baseline anthropometry, physical strength, cognitive function, sleep, and biomarkers of systemic inflammation and musculoskeletal health were taken seven days before the field exercise (Day-7). Follow-up measurements were performed one day prior (Day-1), on day four (Day+4) and seven (Day+7) during, and seven days post (Day+14) field exercise. Movement activity data (GENEActiv accelerometers) were collected throughout the 21-day study period. Focus groups were conducted post field exercise on Day+14. Quantitative data were analysed using a two-way group by time ANOVA with Bonferroni correction. Qualitative data were thematically analysed. **Results:** Greater moderate-vigorous activity was performed by the RIR group compared with the Control group during the seven-day Field Exercise (RIR: 368 ± 44 mins; Control: 321 ± 38 mins; $p < 0.05$). Independent military judgement subject matter experts asserted that the RIR group performed better on Field Tasks. The RIR group slept longer during the Field Exercise (RIR: 369 ± 108 mins·day-1; Control: 272 ± 141 mins; $p < 0.05$). No differences were seen between groups in any other measures. Focus group themes identified greater acceptability of the RIR (compared with in-service rations) for taste, texture, reduced volume, and weight. **Conclusions:** A trial RIR, with reduced weight and volume compared with in-service rations, delivered the energy and nutrient requirements of Royal Marines Commandos during a 7-day field exercise, with high acceptability for taste, texture, and utility. The RIR may support higher intensity work during operational activity. **Military Impact:** Effective operational performance nutrition can be delivered in smaller, lighter rations with high acceptability, and deliver enhanced physical and military task performance during simulated military operations.

Board 10: The influence of pre-sleep protein supplementation on recovery from load carriage in British Army recruits

Shaun Chapman[1], Justin Roberts[2], Andrew J Roberts[3], Henry Ogden[3], Rachel Izard [4], Lee Smith [2], Alex J Rawcliffe [3]

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[2]Anglia Ruskin University, UK
[3]Army Recruit and Initial Training Command, UK
[4]Defence Science and Technology, UK

Purpose: British Army basic training (BT) is physically demanding with recruits completing multiple bouts of physical activity each day with limited recovery. Load carriage is a physically demanding BT activity that induces acute exercise-induced muscle damage (EIMD) and impairs muscle function. Recruits may therefore experience reduced exercise performance capacity and increased injury risk following load carriage. Protein supplementation can accelerate muscle recovery following arduous activity by attenuating EIMD and muscle function loss. This study aimed to investigate the dose response impact of an additional daily bolus of protein prior to sleep on acute muscle recovery following a load carriage test in British Army recruits. **Method:** 99 male and 23 female recruits at the Army Training Centre, Pirbright were randomised to a dietary control (CON), carbohydrate placebo (PLA), moderate protein (20 g; PRO20), or high protein (60 g; PRO60) supplement group. Supplements were administered each weekday from week 3 between 2000 and 2100hrs. The load carriage test consisted of a 4 km tab carrying 20 kg followed by a further 2 km carrying 15 kg. Muscle function (vertical jump height), muscle soreness, and urinary markers of muscle damage were assessed before (PRE), immediately post (POST), 24-hours post (24h-POST) and 40-hours post (40h-POST). A mixed-model analysis of covariance with an adjusted Bonferroni post hoc test was used to examine changes between groups. **Results:** Total protein intake was greater in PRO60 (2.2 ± 0.5 g·kg^{-1}·day^{-1}) and PRO20 (1.7 ± 0.3 g·kg^{-1}·day^{-1}) compared with PLA (1.3 ± 0.3 g·kg^{-1}·day^{-1}) and CON (1.2 ± 0.2 g·kg^{-1}·day^{-1}) ($p > 0.05$). Acute protein supplementation did not impact muscle function at POST (CON = 39 ± 7 cm [Δ 2 ± 8 cm], PLA = 37 ± 6 cm [Δ 0 ± 7 cm], PRO20 = 37 ± 6 cm [Δ −1 ± 5 cm], PRO60 = 38 ± 8cm [Δ 2 ± 7 cm], $p = 0.75$) or 40h-POST (CON = 36 ± 8c m [Δ -1 ± 12 cm], PLA = 37 ± 6cm [Δ -1 ± 11 cm], PRO20 = 36 ± 6 cm [Δ −2 ± 8 cm], PRO60 = 36 ± 6 cm [Δ −1 ± 8 cm], $p = 0.99$). Jump height was greater in PLA (40 ± 6 cm [Δ 5 ± 6cm]) compared with PRO60 (36 ± 7 cm [0 ± 7 cm]) at 24h-POST ($p = 0.04$). Myoglobin increased in all groups, peaking at POST (CON = 128.9 ± 60.5 ng·mL^{-1}, PLA = 151.7 ± 129.0 ng·mL^{-1}, PRO20 = 163.5 ± 162.2 ng·mL^{-1}, PRO60 = 167.5 ± 104.8 ng·mL^{-1}). Concentrations of 3-MH also increased, peaking at 40h-POST (CON = 263.4 ± 91.6 nmol·mL^{-1}, PLA = 294.1 ± 47.4 nmol·mL^{-1}, PRO20 = 264.8 ± 57.5 nmol·mL^{-1}, PRO60 = 265.3 ± 76.8 nmol·mL^{-1}). Urinary muscle damage markers and muscle soreness were not different between groups at any timepoint ($p > 0.05$). **Conclusions:** Protein supplementation did not accelerate acute muscle recovery following load carriage in recruits already consuming protein intakes ≥ 1.2 g·kg^{-1}·day^{-1}). It is likely the load carriage test was not arduous enough, limiting the impact of supplementation. **Military Impact:** Protein supplementation above protein intakes of 1.2 g·kg^{-1}·day^{-1}) following load carriage over similar distances (4 km) and carrying similar loads

(15-20 kg) does not appear to be warranted.

Board 11: Associations of baseline vitamin D level with acute respiratory infections, inflammation markers, and cathelicidin through 14-week follow up in conscripts

Akseli Laaksi [1], Ilkka Laaksi [1], Harri Pihlajamäki [1], Jani P Vaara [2], Tiina Luukkaala [1], Heikki Kyröläinen [2]

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Purpose: In military service, acute respiratory infections can be highly prevalent and lead to days off duty. Therefore, the aim was to study whether there is an association with baseline serum vitamin D levels and acute respiratory infections, days-off duty due to acute respiratory infection, as well as with cathelicidin and inflammation markers in a 14-week follow-up during military service. **Methods:** The follow-up study had 412 voluntary male Finnish conscripts (age 19 ± 1 y, height 1.79 ± 0.07 m, body mass 75 ± 13 kg, body mass index 24.0 ± 3.7 $kg \cdot m^2$) from two different locations and seasons (January and July). The baseline blood samples of the participants were drawn during the first two weeks of their military service. Respiratory tract infection data of the conscripts, for the period of 14 weeks, was collected from the patient information system. All acute respiratory infections and the resulting exemptions assessed by healthcare professionals were recorded in the study. Multivariable-adjusted logistic regression was used showing results by odds ratios (OR) with 95% confidence interval (CI). The regression model was controlled for season, body mass index, aerobic fitness, and vitamin D supplementation. **Results:** Insufficient (< 50 $nmol \cdot L^{-1}$ total 25-hidroxyvitamin D) vitamin D level was associated with increased acute respiratory infections (OR [95% CI], 1.87 [1.05, 3.32) and days-off duty (2.32 [1.29, 4.16]) through the 14-week -follow-up, and it also associated with lower cathelicidin levels (0.49 [0.24, 0.99]) at baseline. However, baseline vitamin D levels did not associate with the studied inflammation markers (CRP and IL-6). **Conclusions:** Sufficient vitamin D level may protect from acute respiratory infections and its protective effect may be mediated through increase in cathelicidin production. Low vitamin D levels did not associate with increased inflammation markers. **Military Impact:** Avoiding vitamin D deficiency could reduce the number of days of absence due to acute respiratory infections and therefore have a positive impact on the performance of individual soldiers and thus on the performance of the troop as a whole.

Board 12: Caloric expenditure of special forces operators during multi-day winter warfare training

Andrea Givens [1], Laura Arrington [1], Jake R Bernards [1], Karen R Kelly [1]

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Purpose: Military training and operations in snowy, mountainous terrain place high physical and cognitive demands on the warfighter, factors that drive up caloric expenditure. Data on

athletes are available from recreational snow sports (cross-country skiing, biathlon); however, there is a lack of data specific to military training. Knowledge of the caloric expenditure of military-specific tasks during winter warfare training will help inform fuelling requirements necessary to operate in mountain and cold weather environments. **Methods:** Special forces operators (n = 13 men, n = 1 woman, age: 31.0 ± 1.1 y, body mass: 88.5 ± 2.6 kg, body mass: 1.81 ± 0.01 m, body fat: 18.5 ± 1.3%, maximal oxygen uptake [VO_{2max}]: 46.7 ± 1.2 $mL \cdot kg^{1} \cdot min^{-1}$, basal metabolic rate: 1857 ± 39 kcal·d-1) assigned to a mountain unit volunteered to participate in the study. Data collection occurred over 4 days in Alaska (−7 to 4 °C). Operators wore Polar® Grit X physiological monitors (Polar Electro, Kempele, Finland) continuously throughout 4 days of training. Devices provided estimated caloric expenditure from heart rate during each day as well as during recorded activities, nightly sleep duration, and daily mileage estimated from steps count. **Results:** Average daily caloric expenditure was 4908 ± 346 $kcal \cdot d^{-1}$ (range 2651 to 8282 $kcal \cdot d^{-1}$)—264% above basal metabolic rate and roughly 55 $kcal \cdot kg^{-1} \cdot d^{-1}$. Mileage estimation from steps was 14 ± 1 $miles \cdot d^{-1}$, and sleep was 6:20 ± 9:29 $h{:}mm \cdot d^{-1}$. Training evolution with lowest total daily caloric expenditure was the sniper range, and evolution with the highest was skinning with a 20 kg pack. Activity caloric expenditure, from lowest to highest, was: 4.5 h, 2.4 km skinning and medevac drills (1536 ± 304 kcal, 341 $kcal \cdot h^{-1}$); 3 h, 2 km skinning (1137 ± 101 kcal, 379 $kcal \cdot h^{-1}$); 4 h, 51 km snow machine transit (1679 ± 120 kcal, 419 $kcal \cdot h^{-1}$); and 5.8 h, 6.4 km skinning with a 20 kg load (2656 ± 389 kcal, 458 $kcal \cdot h^{-1}$). Of note, the snow machine evolution included manual “digging out” due to fresh, deep snow conditions. **Conclusions:** Caloric expenditure during winter warfare training was high; on average 4908 ± 346 $kcal \cdot d^{-1}$, 264% above basal metabolic rate. Lowest caloric expenditure days were at the sniper range, and highest caloric expenditure days (activity) were skinning with load carriage. **Military Impact:** These data will support the science and art of logistical planning for carrying and consumption of nutrition and hydration in winter operational environments.

Board 14: Comparison of weighed-food and food diary methods for measuring energy and macronutrient intake during arduous military training

Sally R Handford [1], Sophie L Wardle [1], Rebecca L Knight [1], Jennifer Wright [2], Thomas J O’Leary [1], Julie P Greeves [1]

[1]Army Health and Performance Research, UK
[2]Defence Science and Technology Laboratory, UK

Purpose: The gold-standard weighed-food method for measuring dietary intake can be challenging in military environments due to variable eating patterns in camp and on field exercise, high researcher burden, and limited participant contact time. Food diaries provide a more practical method than weighed food but may be less precise as participants estimate portion sizes rather than providing exact measurements. This study aimed to quantify agreement between the two methods. **Methods:** Researchers weighed individual food items consumed by British Army Officer Cadets during cookhouse mealtimes over 10 consecutive days of the Officer Commissioning Course. Over the same period, participants completed a daily food diary, unsupervised by researchers. Energy, carbohydrate, protein, and fat intake

were calculated using Nutritics. Data were analysed for participants who completed ≥ 5 d of food diaries and averaged over the included days; data were excluded if no foods were recorded using either method. Energy and macronutrient intake for the two methods were compared using Bland-Altman limits of agreement, and t-tests determined systematic bias. Results: Data from fifteen (of 21) participants were analysed (25 ± 2 y, 1.75 ± 0.08 m, 70.5 ± 11.2 kg; n = 10 women, n = 5 men). There were no significant differences in total energy intake (1713 ± 736 *vs* 1577 ± 747 $kcal \cdot d^{-1}$, $p = 0.263$), carbohydrate (171 ± 79 *vs* 178 ± 92 $g \cdot d^{-1}$, $p = 0.654$), or protein (87 ± 35 *vs* 78 ± 43 $g \cdot d^{-1}$, $p = 0.116$) between methods, but self-reported fat intake was higher with weighed-food (75 ± 35 *vs* 61 ± 30 $g \cdot d^{-1}$, $p = 0.04$). Compared with weighed-food, bias in the food diary was −136 $kcal \cdot d^{-1}$ (95% CI, −1021 to 749 $kcal \cdot d^{-1}$), 7 $g \cdot d^{-1}$ (−113 to 127 $g \cdot d^{-1}$), −9 $g \cdot d^{-1}$ (−52 to 33 $g \cdot d^{-1}$) and −14 $g \cdot d^{-1}$ (−61 to 33 $g \cdot d^{-1}$) for total energy, carbohydrate, protein, and fat intake. **Conclusions:** Daily food diaries are a suitable alternative to gold-standard weighed-food methodology in a military environment, despite fat intake being underestimated. Food diaries also have the added benefit of being able to capture snacks and off-camp feeding. Military Impact: Being able to appropriately capture dietary intake in the military environment will enable better understanding of feeding practices and the benefits of feeding interventions designed to improve the health and performance of service personnel.

Board 15: Macronutrient recommendations for basic military training to mitigate musculoskeletal injury incidence: a narrative review

Nick Dontje [1]

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Purpose: Basic military training (BMT) is the mandatory entry course of the military, varying between 8 - 14 weeks. It is characterised by an arduous training load and globally reported musculoskeletal injury (MSKI) incidence of 21 – 42% in men and 41 – 65% in women. Several nutritional interventions are implemented for micronutrients (*e.g.*, calcium, vitamin D), but specific macronutrient recommendations to lower MSKI incidence are currently lacking. The military dietary guidelines are insufficient considering the recent evidence of relative energy deficiency in the military and updated protein recommendations in periods of energy deficits. This narrative review provides macronutrient recommendations for BMT, specifically to lower MSKI incidence. **Methods:** A literature review was conducted using targeted keywords. Articles were excluded when not meeting the selection criteria of being performed in BMT and reporting energy intake, energy expenditure, macronutrient intake or MSKI incidence. **Results:** Recruits have unique dietary needs, considering the arduous group training and energy demands faced by unaccustomed adolescents that have a widespread in pre-entry military fitness level. The internal load and energy demands (~ 50 – 56 $kcal \cdot kg^{-1} \cdot d^{-1}$) of BMT are comparable to elite endurance athletes, which is mainly caused by the long duration of physical activity (~ 6 – 7 $h \cdot d^{-1}$), rather than the intensity of training. The daily intake of energy (34 – 40 $kcal \cdot kg^{-1}$), carbohydrate (4 – 5 $g \cdot kg^{-1}$), and protein (1.1 – 1.6 $g \cdot kg^{-1}$) did not even meet the lower part of the military and sport nutrition guidelines. **Conclusions:** A substantial number of recruits are at elevated risk of MSKI due to the combined effects of low energy availability, low military fitness, low diet quality, and high mechanical loading in BMT. **Military Impact:** Supplementation studies have shown the potential that increasing energy intake lowers MSKI incidence, but the specific effects of protein and carbohydrates supplementation remains to be investigated.

Board 16: Effectiveness of food supplements among soldiers during an outfield military exercise

Rachel L Yeow [1]

[1]Singapore Armed Forces, Singapore

Purpose: Current feeding in the field involves the use of combat rations. Use of food supplements in the form of energy gels and bars could enhance soldiers' performance. Therefore, the aim of the study was to determine the effectiveness of supplements. Secondary aims were to profile the food consumption behaviour as well as energy intake of soldiers undergoing an outfield military exercise. **Methods:** Energy gels and bars were provided in addition to standard combat rations to soldiers during an outfield military exercise. Feedback was collected through an online survey conducted with 62 male soldiers. Soldiers were questioned on whether they consumed the supplements and why, as well as their consumption behaviour. Energy intake was determined through the calculation of nutritional information from empty food wrappers and leftover food collected from 15 participants. **Results:** 88.7% of the participants felt that that the supplements were beneficial with the top reasons for consumption ranked as the ability of the supplements to (1) increase energy and reduce fatigue, and (2) enhance perceived performance. Participants also felt that they were better able to sustain their physical as well as cognitive performances. However, the calculated energy intake suggested a deficit over a 24-hour period. **Conclusions:** The use of supplements in addition to combat rations has been shown to be well accepted and beneficial for the soldiers through an improvement in energy, reduction of fatigue, and enhancement perception of performance, despite given the energy deficit. **Military Impact:** Food supplementation at crucial points during military training and operations can provide additional energy and enhance perception of performance. This is especially impactful given the background of energy deficit. Such supplements should be considered as part of the soldiers' combat rations. Further studies should explore methods to facilitate increased consumption of combat rations to address the energy deficit.

Board 17: Lipid profile improved in young soldiers during energy-restricted military training

Tarja Nykänen [1], Tommi Ojanen [2], Jani P Vaara [3], Mikael Fogelholm [4], Heikki Kyröläinen [5]

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[3]National Defence University, Finland
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[5]University of Jyväskylä, Finland

Purpose: Energy-restricted diets, endurance-type exercise, and consequent weight loss are effective in improving total cholesterol (CHOL), low-density lipoproteins (LDL), high-density lipoproteins (HDL), and triglyceride (TRI) levels, but there is a lack of knowledge in acute responses of negative energy balance on blood lipids. Thus, the purpose of the study was to investigate the short-time effects of energy-restricted military field training on cholesterol and triglyceride values in young and normal-weight conscripts. **Methods:** Participants were divided into two groups: the field exercise group (FEX; n = 25, age 19.6 ± 0.8 y, BMI 23.1 ± 2.4 kg·m²) had a continuous 7-day military field training period with severe energy restriction, while the recovery group (RECO; n = 20, age 19.8 ± 1.3 y, BMI 23.1 ± 3.0 kg·m²) had a 2-day recovery period with regular meals in the middle of training (D3-5). Blood samples were collected at days D−3, D3, D5, and D7 for analyses of total cholesterol, HDL, LDL and triglycerides. Paired t-tests with Bonferroni corrections were used to compare means at different time points and between the groups. **Results:** Body mass reduced −3.0 ± 1.4 kg (FEX) and −4.7 ± 1.4 kg (RECO) (both $p < 0.001$). Total cholesterol decreased from 4.1 ± 0.7 to 2.9 ± 0.7 $mmol·L^{-1}$ in FEX ($p < 0.001$) and from 4.3 ± 0.6 to 3.7 ± 0.5 $mmol·L^{-1}$ in RECO ($p = 0.002$) from D-3 to D7. After the first field training phase (D3), LDL and triglycerides decreased and HDL peaked in both groups ($p < 0.001$ all, except for LDL in RECO $p = 0.002$). LDL decreased until the end, but HDL and triglycerides recovered towards baseline values at D3-7. LDL and triglycerides differed between groups at D5 and D7 (LDL $p = 0.008$ and $p < 0.001$; triglyceride $p < 0.001$ and $p = 0.08$; respectively) and total cholesterol at D7 ($p < 0.001$). **Conclusions:** Total cholesterol, LDL, HDL, and triglyceride values were all improved in short-time energy restriction. Total cholesterol and LDL remained at lower level, whereas HDL and triglycerides returned to baseline values after the first field training phase. Furthermore, 2-day recovery normalised LDL and triglyceride values compared with FEX. Energy deficit and weight loss in strenuous military field training stimulated lipid metabolism in conscripts, which enhanced lipid profile for cardiometabolic health. **Military Impact:** Short and strenuous military field training with weight loss had a positive effect on lipid profile even in young and normal-weight soldiers.

Board 18: Longitudinal evolution of body composition and energy expenditure during a basic course for Special Operations Regiment (SOR BC)

Annelore Gemmeke [1], Patrick Mullie [1], Damien Van Tiggelen [1]

[1]Belgian Defence, Belgium

Purpose: The Special Operations Regiment Basic Course (SOR BC) follows the Military Initiation Phase and is an eight-week program that prepares soldiers to apply for more specialised Paratrooper and Special Operations training. In this study, we aimed to estimate energy expenditure, body composition evolution, and probability of success. **Methods:** The SOR BC 2022 was completed by 88 participants, while 38 participants did not complete. Body composition was assessed with Tanita MC-780U Multi Frequency Segmental Body Composition Analyzer at baseline and at the end. In order to determine energy expenditure, 41 participants wore triaxial accelerometers (Actigraph GT3X). Using Henry et al. equation, we calculated the resting metabolic rate in kcal·d-1: 14.4 × body mass (kg) + 313 × height (m) + 113; 10% was added for thermic effect of food. **Results:** Participants' mean ± SD age was 25.0 ± 4.1 y, body mass was 77.6 ± 8.6 kg, and fat mass was 15.3 ± 3.4 %. A decrease in body mass from 78.3 ± 8.8 kg to 76.4 ± 8.0 kg ($p = 0.01$) was observed, as well as a decrease in fat mass by 3.1 ± 1.8 kg and an increase in muscle mass by 1.2 ± 1.7 kg. The decrease in fat mass equated a loss of 21,700 kcal or 362 kcal·d^{-1}. A mean ± SD energy expenditure by physical activity of 1,943 ± 654 kcal·d^{-1} was recorded, with a minimum and maximum of 572 and 3,036 kcal·d^{-1}. The total amount of energy expended on average was 4,088 ± 710 kcal·d^{-1}, although it varied from 2,975 to 5,222 kcal·d^{-1}. In order to examine the relationship between success rate as a dependent variable and baseline body fat mass (higher than 12% *vs* lower than 12%), a logistic regression analysis was conducted. A body fat mass higher than 12% was associated with an increase in success rate of 154% (95% CI [10%, 483%]) compared with a body fat mass lower than 12%. **Conclusion:** A major finding of this study is that fat mass decreased, and baseline fat mass was associated with success rate. During this military training program, there was a cluster of ectomorphic non-completers with low fat mass and low muscle mass. **Military Impact:** According to the findings of the present study, tactical athletes must maintain a high physical level despite consuming a suboptimal diet and dietary supplements. In such circumstances, an increase in muscle mass in combination with a slight increase in body fat mass may prove advantageous. In the future, research should be directed toward achieving an optimal energy environment.

Board 19: The impact of Holistic Health and Fitness (H2F) on the nutritional readiness of U.S. Army soldiers: results from the 2023 Soldier Readiness Survey

Brenda D Bustillos [1], Stephanie Muraca [2], Michael S McGurk [2]

[1]Defense Health Headquarters, USA
[2]US Army Training and Doctrine Command, USA

Purpose: More than 70% of Americans between the ages of 17 and 24 years are ineligible to serve in the U.S. military for various reasons. Of those currently serving, performance is degraded by obesity, injury, and poor health behaviours. The U.S. Army is transitioning from a system that provides reactive healthcare to one that focuses on soldier performance, preventive health, and health promotion. The 2023 Soldier Readiness Survey gathered information about the current state of Soldier readiness and assessed the impact of H2F on the nutritional readiness of U.S. Army soldiers. **Methods:** Between 7 October and 25 November 2022, all U.S. Army soldiers received between two and three emailed invitations to participate in the confidential online survey. The survey assessed readiness outcomes including current-state physical fitness / wellness, sleep duration and quality, dietary beliefs and practices, and engagement in adaptive and maladaptive behaviours. Awareness and perceived impact of the H2F system was also assessed. OLS regression was used to estimate the effect of H2F unit status (resourced vs non-resourced) on nutrition outcomes, while controlling for factors such as age and gender that could also affect behaviours and perceptions. **Results:** Of the ~1,090,500 Soldiers serving in the Army across Active Duty (~482,420), National Guard (~337,530), and Reserve (~270,560) components, ~15,200 (1.4%) responded to the survey. Respondents were mostly male (80%), serving in non-combat arms positions (70%), had an average time in service of 14 years, were mostly non-commissioned officers (45%), and had at least one combat deployment (72%). Female soldiers were more than twice as likely to have seen a civilian dietitian, and more than four times as likely to have joined a civilian weight management program compared with male soldiers. Of the respondents, 23% experienced food insecurity in 2022. **Conclusions:** As the H2F footprint grows, so too grows the demand for better fuelling options, access to registered dietitians, and soldier awareness of nutritional readiness. Results from the Soldier Readiness Survey will inform food program stakeholders across the military nutrition environment who build strategic frameworks that aim to improve equity, access, availability, and affordability of nutritious foods. **Military Impact:** The H2F System encompasses the "Whole Soldier" concept which aims to improve, restore, and maintain resilience and performance of the total Army by building holistically healthy soldiers who can thrive while working in any capacity. The scope of this evidence-informed initiative represents a dramatic shift in how the U.S. Army optimises soldiers' physical and non-physical capabilities.

Posters 3: Trial Design, Methods, Conduct, and Reporting

Thursday 14th September, 12:15 to 13:45

Board 20: Repeatability and reproducibility of a standard test method for measuring head-supported mass properties

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Purpose: To establish the repeatability and reproducibility for measuring mass properties-centre of mass (CM) and moment of inertia (MOI) of head-borne equipment utilising a novel test fixture and mass properties instrument (MPI). **Methods:** Existing procedures and equipment for measuring CM and MOI of head-borne equipment were evaluated to identify sources of measurement error and to optimise test efficiency. A MPI which measures both CM and MOI was utilised to minimize error. A novel test fixture was designed and headforms modernised to improve and maintain alignment between headforms and the MPI. The fixture allows for positioning headforms in six orientations needed for test item CM location (X, Y, Z) measurements and the six MOI measurements needed to calculate the inertia tensor. A 3D coordinate measuring machine (CMM) was incorporated to track headform and helmet alignment pre- and post-measurements. A gauge repeatability and reproducibility analysis was performed to determine part, fixture and operator variability. Multiple head-borne configurations were measured three to ten times by seven operators using two MPIs and two fixtures. Six head-borne equipment configurations were tested: Advanced Combat Helmet (ACH) sizes small, medium, and large, Integrated Head Protection System size large, ACH with PVS-14-night vision device stowed and deployed, ACH with M-50 Joint Service General Purpose Mask, and the Aircrew Integrated Helmet System (AIHS). The measured CM and MOI means, standard deviations, variance, and coefficient of variation (CV) were calculated. **Results:** For CM, the variances ranged from 3.2 to 5.7 mm2 along the Z-axis (superior-inferior), 0.2 to 1.7 mm2 along the Y-axis (right-left) and 0.2 to 5.9 mm2 along the X-axis (anterior-posterior) except for the ACH with PVS-14 Stowed and the AIHS. For MOI, variances were largest for the ACH with PVS-14 stowed and deployed. Overall, the greatest proportion of the observed variance was due to operators. The CMM helmet to headform alignment measurements were correlated to the variations in the CM offsets. **Conclusions:** This research verified the procedures and test fixture developed. Variance was primarily due to the test item configuration and operator (helmet placement on headform). Both factors are important to consider when developing guidelines for mass properties measurements. **Military Impact:** Having a repeatable and reproducible method for measuring CM and MOI of head-borne equipment is critical to establishing and understanding the link between mass properties, soldier performance, and injury risk from head-borne loads.

Board 21: Rapid assessment of changes in jump performance following a 36-hour field exercise using a semi-automated force-plate system

Patrick Bray [1], Christopher Vine [1], Faye Walker [1], Carla Rue [1], Nick Schofield [1], Holly Bassett [1], Lauren Buck[1], Kimberly Ashdown[1], Aaron Greenhouse-Tucknott[1], Tessa Maroni [1], Katrina Hinde [2], Emmeline Elliott [2], Mark Rayson [3], Edward Knight [4], Sam D Blacker [1], Steve Myers [1]

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Purpose: To measure changes in physical performance parameters as potential predictors of military performance. Force plate data can be utilised for injury management and quantifying performance. However, force plate data are often outputted in a raw format requiring time consuming analysis by specialist staff, limiting their usability in large populations such as the military. The development of portable semi-automated force-plate systems, providing instantaneous outputs via tablets/phones, offer increased data usability and fidelity. These developments increase force plate data utility to understand soldier performance (e.g., injury management, training effects) and describe neuromuscular fatigue associated with military activities such as field exercises. **Methods:** As part of a larger Defence Science Technology Laboratory funded study rebound countermovement jump (RCMJ) performance was measured in 44 Officer Cadets (age 24 ± 3 y, height 1.80 ± 0.08 m, body mass 84.9 ± 9.8 kg) before and after a 36-hour non-tactical field exercise, completed during the Regular British Army Commissioning Course. It involved covering at least 50 km over challenging terrain, carrying ~ 25 kg. Data were collected in a field environment using a validated, semi-automated force-plate system (HD-Force-Plates, Hawkin Dynamics, USA) providing instantaneous data analysis and storage to a tablet. Volunteers completed three best-effort RCMJ pre- and post-field exercise. Pre to post change in jump height, CMJ modified Reactive Strength Index (RSI), CMJ time to take-off, rebound jump height, and rebound modified RSI were analysed using paired t-tests. **Results:** CMJ jump and rebound jump heights reduced by 16% (pre 0.25 m; post 0.21 m; $t_{(131)} = 4.25$, $p < 0.001$) and 7% (pre 0.28 m; post 0.26 m; $t_{(131)} = 2.793$, $p = 0.002$), respectively. CMJ modified RSI and rebound modified RSI reduced by 19% (pre 0.30; post 0.25; $t_{(131)} = 7.723$, $p < 0.001$) and 10% (pre 0.47; post 0.42; $t_{(131)} = 3.083$, $p = 0.002$), respectively. Time to take off increased by 8% (pre 0.82; post 0.88 s; $t_{(131)} = -2.965$, $p < 0.001$). **Conclusions:** Performance in all reported variables reduced post-exercise inferring muscular fatigue and potentially compromised military performance. This study demonstrates the equipment's utility and sensitivity to identify changes in muscular function and therefore usefulness for field trials. The semi-automated force-plate system required no additional resources or analysis, it provided an instantaneous measure that could be used to infer fatigue, while also storing raw data, facilitating subsequent extended analyses. **Military Impact:** In an austere environment semi-automated portable force plates have the capability to enhance the understanding of relevant jump metrics as a measure of neuromuscular function within occupational settings without the need for specialist analysis or knowledge, which ultimately may support quantification of fatigue and injury management.

Board 22: Effects of body size on range of motion measurements in product testing

Hyegjoo E Choi-Rokas [1], K Blake Mitchell [1], Todd N Garlie [1]

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Purpose: Soldier mobility, beyond completion times, is often difficult to measure objectively. Range of motion (ROM) has become a surrogate for mobility, allowing researchers to quantitatively measure body movement, usually confined within a single joint, and to quantify the impact clothing/equipment make on that movement. While measurement units can document these performance degradations, it was hypothesized that utilizing percent degradation, relative to an individuals unencumbered performance (i.e., 100%), would allow for consistent results across different body types (assumption 1) while still maintaining the sensitivity to differentiate between equipment configurations (assumption 2) independently and across body types (assumption 3). **Methods:** Thirteen ROM measurements that were most likely impacted by wearing body armour were selected for this study. These ROM measurements encompass movements of the torso, neck, limbs, and the entire body. Three different sample groups (all male active-duty Soldiers) with different body types were recruited (random sample [n = 21], central sized [n = 10], and extreme sized [n = 9]). They performed all ROM measurements in three armour configurations: best available fit size (BF), one size decreased from BF, and one size increased from BF. All ROM measurements were converted to percentages of participants' maximum capability and averaged. A mixed design ANOVA, with Bonferroni adjustments as necessary ($\alpha = 0.05$), was performed to compare percent degradation for the averaged movement between groups (assumption 1), between configurations (assumption 2) and the interaction between groups and configurations (assumption 3). **Results:** No significant differences in ROM percent degradations between groups ($F_{(2, 31)} = 1.497$, $p > 0.05$) were seen confirming they were not affected by different body types. Percent degradation remains sensitive to differentiate between fit configurations ($F_{(2, 68)} = 11.22$, $p < 0.001$) where degradations in the BF and decreased, were statistically equivalent to each other, however, in the increased, mobility was further degraded. Finally, there was no statistically significant interaction effect ($F_{(4, 62)} = 0.49$, $p > 0.05$), indicating that different body types were similarly impeded by armour configuration. **Conclusions:** When represented in percentages relative to their own capability, different body types showed similar levels of mobility degradation on ROM measurements while still maintaining the sensitivity to differentiate between equipment configurations consistently across different body types. **Military Impact:** When conducting product testing, researchers are often limited in their ability to assess a diverse set of body types, within the limited samples and user populations they have available. This study supports that body size will not play a significant role in objective ROM performance outcomes, therefore making it a strong evaluation metric for use with limited sample sizes, as is frequently the case for military product user evaluations.

Board 23: The benefits and practicality of utilising a baseline data collection period in research at military training establishments

Faye Walker [1], Christopher Vine [1], Patrick Bray [1], Benjamin Sharpe [1], Kimberly Ashdown [1], Aaron Greenhouse-Tucknott [1], Sam D Blacker [1], Iain Greenlees [1], Tessa Maroni [1], Katrina Hinde [2], Emmeline Elliott [2], Mark Rayson [3], Edward Knight [4], Steve Myers [1]

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Purpose: Officer Cadets (OCdt) training at the Royal Military Academy Sandhurst face significant physical, cognitive, and time management demands. Across the 44-week Regular Commissioning Course (CC), the quantity of physical training, field exercises, lectures, and other military activities varies. Research utilising one-off ‘snapshot’ measurement periods may misrepresent the demands of the CC at the time of interest. Instead, a multi-day baseline period may better account for the variability in factors such as workload, sleep, and fatigue experienced by OCdts. **Methods:** As part of a larger study to identify predictors of military performance, 28 male OCdts (age 24 ± 2 years) completed a battery of computer-based psychophysiological measures prior to breakfast (06:00 to 06:30 hh:mm), across a five-day baseline period in week seven of the CC. Measures comprised of two cognitive tests (Go-/No-Go, Psychomotor-Vigilance-Task), self-reported sleep duration and quality, and subjective measures of sleepiness (Karolinska Sleepiness Scale) and fatigue (Samn-Perelli Fatigue Questionnaire). Measures were presented in the same order and took 10 min to complete. Results are reported as group means and ranges. **Results:** Overall compliance for pre-breakfast baseline testing sessions was 99%, enabling a robust baseline for each OCdt to be established. OCdts reported a mean daily sleep duration of 06:41 hh:mm per night (range: 06:24 to 07:04 hh:mm) with “average” sleep quality across the five nights. These results were mirrored with consistent sleepiness (“Some signs of sleepiness”) and fatigue (“A little tired, less than fresh”) scores. Mean reaction time remained relatively stable for the Go-/No-Go task (range: 299 to 312 ms) and PVT (range: 334 to 360 ms), across days. However, a reduction in error rate was observed for the Go-/No-Go task (day 1: 10.1% *vs* days 4 and 5: ~2.5%) identifying a potential learning / practice effect. **Conclusions:** Consistency in self-reported measures of sleep, sleepiness, and fatigue, provided high confidence that those data collected were representative of the course demands at that time. Utilising the time around meals allows for a regular testing window in an otherwise highly variable, heavily populated training timetable. This method facilitates data collection at the same time of day, and at the same relative time to participants’ wake-up time, controlling for the effect of diurnal variation. **Military Impact:** The time available around meals offers the military an opportunity to capture simple usable data (*e.g.*, fatigue and sleepiness measures), with minimal impact on training schedules and high compliance. Regular data capture could help monitor OCdt fatigue / readiness and support training and ensure stable baseline data for pre- and post-measures.

Posters 3: Female Physiology

Thursday 14th September, 12:15 to 13:45

Board 24: Self-reported hormonal contraceptive use in female recruits during British Army basic training

Bethany J Moxham [1], Rebecca L Knight [1], Thomas J O'Leary [1], Sophie L Wardle [1], Julie P Greeves [1]

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Purpose: Hormonal contraceptives (HCs), which contain synthetic oestradiol and/or progesterone, are used to prevent pregnancy and/or help manage menstrual bleeding. There are no published data reporting the prevalence and changes of HCs use in female recruits during British Army basic training. Army training is a unique environment that is physically arduous and provides trainees with the necessary skills and physical fitness required for careers in the Armed Forces. Due to the younger age of those in basic training, the HCs choices of women could have important clinical implications for injury risk and achieving peak bone mass. The aim of the study was to identify the prevalence and pattern of HCs use during Army basic training. **Methods:** An online survey was distributed to all British Army female recruits (240) at the end of their basic training within standard entry (14-week), infantry (26-week) and officer (44-week) courses. Ninety-four women out of 240 women (39%) responded about patterns of HCs use prior to joining the Army and throughout basic training, reasons for HCs use, and musculoskeletal injury history. Binary logistic regression was used to evaluate associations between demographics (age and rank [Officer, Soldier]) and HCs use at the start and end of training, and whether HCs use changed during training (0 = no, 1 = yes). **Results:** Fewer female recruits were using HCs at the start than end of basic training (51 vs 59%) and 15% changed their HCs method during basic training. The most used HCs was the combined oral contraceptive pill (26%). There were no associations between age, rank and HCs use at the start or end of training, or with change in HCs use. **Conclusions:** HCs use is common in British Army female recruits and higher than that of the general UKs population. HCs use may be higher in basic training than other populations due to the advantages of controlling menstrual bleeding when living in the block and in the field. Further investigations should assess whether HCs use is related to variations in health outcomes between trainee populations, to understand the impact HCs use has on physical performance and health. **Military Impact:** It's important for Military/Defence to have knowledge and a better understanding of the consequences of using HCs. The use of HCs may give negative health effects for female soldiers, i.e., stress fracture risk, bone mineral density. This could be an important impact for the Military/Defence, due to consequences that could arise and lead to discharging as of right.

Board 25: Comparison of body segment masses between male and female postmortem human specimens

Meghan O'Donovan [1], Rebecca E Fellin [1], Kari L McKenzie [1], Carolyn K Bensel [1], Christopher B Albery [2]

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Purpose: Biomechanical models are commonly scaled by participant mass, which is usually based on scaling factors from exclusively male post-mortem human specimens. The purpose of this study was to identify if body segment masses of male and female post-mortem human specimens were different. **Methods:** Twenty-seven post-mortem human specimens, 12 male (mean ± SD, aged 71.3 ± 16.4 y, height 1.78 ± 0.09 m, body mass 82.1 ± 12.4 kg) and 15 female (aged 70.8 ± 11.6 y, height 1.64 ± 0.03 m, body mass 66.3 ± 11.6 kg), were segmented into 15 segments, head, torso, pelvis, right and left upper arm, lower arm, hand, thigh, lower leg, and foot. Each segment mass was recorded. Data were analysed with a MANCOVA to identify gender differences between segment masses using height and body mass as potential covariates. Covariates were included in the analysis only if the model identified they were significant ($p \leq 0.05$). A Bonferroni correction was used to identify body segment differences between genders. **Results:** In the MANCOVA, body mass was a significant covariate ($p < 0.01$), and height was not a significant covariate ($p = 0.27$). With mass as a covariate, there was a main effect of gender ($p < 0.01$). The MANCOVA revealed the mass of the female post-mortem human specimens was less than that of the male post-mortem human specimens for the head as well as the right and left hand, forearm and foot (all $p < 0.01$). None of the segments were significantly heavier in the female specimens than the male specimens ($p \geq 0.06$). The greatest difference was that the female head segment was 0.49 kg less than the male head segment, which equated to a 13% mass difference (3.50 to 3.99 kg). The hand masses were only 0.14 kg less in female specimen than male specimens, but that equated to 30% lower mass in female specimens, (0.47 to 0.33 kg). The foot masses were 25% (0.22 kg) less and the forearm masses were 17% (0.19 kg) less in female compared with male specimens. **Conclusions:** In a large cohort of male and female post-mortem human specimens, segmental masses of the smallest body segments differed significantly by gender after including total body mass as a covariate. **Military Impact:** Biomechanical models without separate male and female scaling factors may not fully characterise personnel, which may lead to an over or under estimation of segmental and joint loads.

Board 26: Defining a sports bra for fitness - U.S. Army

Michael S McGurk [1]

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Purpose: To provide solutions developed by the U.S. Army based on complaints from female soldiers that available sports bras were insufficient in terms of support and modesty to allow them to properly conduct physical fitness training. At entry, U.S. Army female soldiers were provided a clothing allowance of $86 to procure the necessary sports bras at the Base Troop store. Guidance from the U.S. Army was for soldiers to purchase 7 bras. The type of sports bra procured was left to the discretion of the soldier, and the available monetary allowance forced the purchase of low cost and low-quality items. From the complaints, the Army had low confidence that they were adequately providing female soldiers with the education and means to acquire properly fitted and functional breast support during physical training. **Methods:** Due to the complexity and privacy concerns, it was determined that multiple complementary methods were best suited to addressing the research goal. It was determined that multiple on-line surveys, combined with field testing trials, and subject matter experts' judgment and input could best provide a complete solution. Following a literature review of existing projects from around the globe as supporting material, the U.S. Army undertook two significant survey efforts to better define the Army issues (n = 19,000). After obtaining a clearer picture of the issues from the survey, the U.S. Army undertook field trials while simultaneously pursuing policy changes. The field trials were a trial of both educational material and of fitting/use of commercial off the shelf designs to determine desired attributes. For the field trials, a training battalion (n = 150) had commercially available sports bras professionally fitted, and each user reported on the fit and comfort of the sports bra over a 10-week training period. **Results:** There was a direct increase in the funding of sports bras by over 300%. Quality, supportive, functional sports bars were determined to cost on average $30 to $60 per item. The Army identified key features to establish baseline requirements of sports bra design for on hand stock, available for purchase by soldiers. The Army initiated an additional training and education program for female recruits concerning bra fitting and breast health, and developed a pamphlet to assist with them when purchasing a sports bra. **Military Impact:** The ability to provide proper, well fitted and functioning equipment to all soldiers is of critical importance to Defence.

Board 27: To fit or not to fit: How the body armour issuing process differs for male and female

K Blake Mitchell [1], Todd N Garlie [1], W Johnson [1], Hyegjoo E Choi-Rokas [1], Edward Hennessy [1]

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Purpose: To better understand female's experiences with their body armour systems, a questionnaire was developed (2022) asking Soldiers to document how the fit of those systems impacted their job and mission performance. Participants were queried regarding how they were fit for their body armour systems, the issuing process, availability of sizes, and how the fit impacted performance. **Methods:** An online survey was distributed by social media and word of mouth. 403 respondents (308 males and 95 females) completed most of the questionnaire section on body armour issuing. Males were primarily US Army active-duty enlisted combat arms. Females were primarily US Army active-duty but were closely split between enlisted and officers and closely split between combat arms, combat support and sustainment support roles. Questions were developed by US Army researchers who had extensive experience assessing a variety of body armour systems for multiple defence agencies and were familiar body armour fit and performance issues. **Results:** Chi square tests were conducted on the frequencies of responses by females and males. The results summarize the selected significant test outcomes ($p < 0.05$), in all cases females are compared to males, and reported in that order. During the fitting process, females were less likely to try on the body armour (40.0% *vs* 19.8%). Females were less likely to report having a plate held to their body to size them (7.4% *vs* 31.8%). Females were also less likely to report being measured for chest circumference (6.3% *vs* 21.4%), stature (20.0% *vs* 32.1%), and front torso or waist length (6.3% *vs* 19.2%). Females were more likely to select their own size, without being sized by trained issuing personnel (18.9% *vs* 6.8%) or to be handed a size without an option (28.4% *vs* 5.2%). Compounding these differences, females were also less likely to have their size available for issue (15.8% *vs* 4.9%). Unsurprisingly, this led to a worse fit for females than males. On a four-point scale, only 23.1% of females rated fit positively (good or excellent), compared to 49.3% of males. While the findings from this survey are limited due to sample size and potential imbalances in demographics, it does raise the question of if a potential difference in how Soldiers are fit, based on their gender, is occurring. **Conclusions:** This work highlighted experiences differences for females and males in the body armour process, where females were less likely to have fitting techniques used and received poorer fitting body armour systems. Further research should be conducted to validate and understand why this may be occurring. **Military Impact:** Despite the best efforts of equipment designers to improve the functionality and reduce performance impacts of body armour, if females are not being properly sized (measured, trying on multiple sizes, availability of all sizes) those efforts are fruitless, and females will continue to experience performance related issues from the ill-fitting equipment.

Board 28: Relationship between subjective ratings of fit and performance for female Soldiers

K Blake Mitchell [1], Todd N Garlie [1], W Johnson [1], Hyegjoo E Choi-Rokas [1], Edward Hennessy [1]

[1]US Army Combat Capabilities Development Command Soldier Center USA

Purpose: Researchers were interested in querying female Soldiers regarding their subjective experiences with body armour and how its fit impacted their mission performance. As part of a larger online questionnaire on this subject, participants subjectively rated the fit of their body armour system and how their body armour impacted their ability to complete a range of basic soldiering tasks. **Methods:** An online survey was distributed by social media and word of mouth in 2022, with 65 total responses and 56 primarily active-duty US Army female Soldier responses, to the rating of fit (age: 32 ± 8 y, time in service: 9 ± 6 y). Of those who responded, 22 (39.3%) had a poor fit, 19 (33.9%) had a fair fit, 12 (21.4%) had a good fit, and 3 (5.4%) had an excellent fit. **Results:** Spearman's rank correlation was computed to assess the relationship between Individuals' fit rating and a series of questions focused on how the body armour impacted their ability to perform basic movements and military tasks. Statistically significant results ($\alpha < 0.05$), unless otherwise noted, are summarised as follows. Each movement was rated on a scale of no impact, some impact, moderately impactful, very impactful, and extremely impactful. Most of the basic movements (*e.g.*, standing, twisting, raising arms) had no significant correlation with fit rating. Lying in the prone position and bending over to pick up items on the ground were impacted by fit. Most dynamic mission movements and tasks were significantly correlated to fit, including running, jumping, high crawl, low crawl, all three weapon shouldering postures (standing, kneeling, prone), high step, climbing over walls/obstacles, climbing through objects, climbing over barriers, and climbing in and out of a vehicle. In all cases, as body armour fit was rated worse (i.e., poor fit), performance was more impacted. **Conclusions:** While the findings from this survey are limited, it does support that poor fitting body armour impacts military movements and task completion, especially for tasks that require a high level of mobility and body movement. Here, 73% rated their armour fit as either poor or fair, indicating that body armour fit

is a significant issue for female Soldiers, a challenge the US Army acquisition community has been trying to tackle with the latest systems. **Military Impact**: Ensuring that all our troops, but especially our female Soldiers, are receiving armour that fits them and allows them the mobility they require to execute their jobs and their missions is essential to the success of our military.

Posters 3: Cognitive Performance

Thursday 14th September, 12:15 to 13:45

Board 29: Cognitive load, distraction, and information pickup in a dynamic visual search task

Martin Fultot [1], Brian Higginson [1]

[1]Galvion, USA

Purpose: Augmented reality (AR) is playing an increasingly prominent role in military technology. However, augmenting vision through heads-up displays increases the risk of cognitive load or distraction through iconology salience. Even peripheral, non-occluding iconology can potentially drive gaze away from the real visual field. Moreover, if iconology is relevant to the task, its distracting power depends on more than sheer stimulus salience. This study assessed the impact of peripheral iconology on visual search performance measured with eye-tracking as a function of both task relevance and salience. The main task was to find a target optotype on a search field while icons on the periphery of the visual field could either be irrelevant or help by reminding the shape of the target, in which case the dual task consisted of attending to the peripheral icons to retrieve information when needed. **Methods:** Eighteen participants (11 females, 7 males, mean age = 19) were instructed to press a button every time they spotted the target in a flowing field of random optotypes under four conditions: no AR icons, static AR icons, salient AR icons, and relevant AR icons (reminding the target). Eye-tracking was used to measure error rate and reaction time as well as gaze position. Three trial repetitions per condition were used. **Results:** Repeated-measures ANOVAs showed that gaze fixation centroid significantly changed across conditions ($F_{(3,51)} = 2.936$, $p = 0.042$), with relevant icons pulling gaze significantly more than all other conditions ($p = 0.044$). However, the pull change did not significantly affect error rate as measured by the F-Score ($F_{(3,48)} = 0.490$, $p = 0.691$) nor reaction time ($F_{(3,51)} = 1.230$, $p = 0.308$). **Conclusions:** Irrelevant yet salient icons do not appear to pose a significant risk of distraction during visual search. Relevant icons do have an effect on gaze that pulls away from search. However, the task distribution over field search and AR information pickup is not taxing enough to decrease main task performance. Conversely, relevant information also did not improve performance, which suggests a possible trade-off between the positive effect of having information available to help the task and the cost of picking it up when the information is located peripherally. **Military Impact:** Military AR applications need to quantify information pickup cost as another factor added to salience, occlusion, and cognitive load in order to design AR interfaces.

Board 30: Accuracy-reaction time trade off in dynamic marksmanship task under different mechanical and cognitive loads

Martin Fultot [1], Brian Higginson [1]

[1]Galvion, USA

Purpose: Marksmanship is affected, among other things, by A) Mechanical loads imposed by the inertial properties of helmets and B) Cognitive workload and situational awareness changes induced, for instance by Night Vision Goggles (NVGs) which reduce the field of view. This study investigated the impact of different helmet-induced mechanical and cognitive load conditions on marksmanship measures of accuracy and reaction time (RT) as well as the trade-off between the latter two. It was hypothesized that overall shooting performance would be better under a condition without mechanical or cognitive loads, but that only accuracy or reaction time would worsen under loads, but not both together. **Methods:** Six participants with shooting experience performed a dynamic marksmanship task under three different conditions: helmet only, helmet with deployed NVGs, and Helmet with deployed NVGs and counterweights. The task consisted of turning left or right towards a spinning device that would then reveal a shoot or no shoot target. If the "no shoot" target was selected first, the participant would still have to shoot the "shoot" target as quickly as possible. Each participant repeated the task three times under all three conditions. RT was measured as the time from beginning of movement to the two shots, in seconds, and accuracy as the distance of the shots from the centre of the box in cm. In addition, a combined metric, *i.e.*, "absement", or RT times accuracy was introduced, to capture the trade-off between them. **Results:** Repeated Measures ANOVA showed that accuracy (M = 5.88, SD = 2.92) did not vary significantly between Helmet Only, NVG only and NVG and counterweight conditions (F(2, 10) = 0.184, p = 0.834). RT (M = 1.29, SD = 0.48) varied significantly ($F_{(2, 10)}$ = 9.42917, p = 0.005) with Helmet Only being faster (M = 1.100, SD = 0.346) than NVG (M = 1.420, SD = 0.486) and NVG and counterweight (M = 1.355, SD = 0.548). A significant difference in absement was found across conditions ($F_{(2, 10)}$ = 4.520, p = 0.040). **Conclusions:** Load differences had an impact on marksmanship performance. However there the lack of significant difference between NVG deployed and NVG plus counterweight deployed suggests that perceptual load and not mechanical load was most responsible for shift in performance. Accuracy did not change, but more time was taken to aim and shoot. A significant absement metric further indicates that there was no trade-off between accuracy and RT. **Military Impact:** The study suggests that perceptual factors (e.g., visual encapsulation) can be more prominent in affecting shooting reaction time than mechanical factors (*e.g.*, NVG weight). From a military point of view, this invites a discussion about technological priorities linked to visual augmentation equipment.

Board 31: The effects of probabilistic information and gaming experience on a performance in a military specific shoot / don't-shoot task

Christopher Vine [1], Oliver Runswick [2]

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Purpose: In performance environments, individuals often receive situation-specific context in the form of probabilistic information. Skilled performers can efficiently integrate this information with live sensory input to inform their judgements. However, they can also rely too heavily on prior context; leading to decrements in performance, especially in environments where information is uncertain. Here we investigate the performance of first-person shooter gamers and novices on a military specific shoot / don't-shoot task under conditions providing different probabilistic information. **Methods:** 22 PC based first-person shooter gamers and 22 novices completed a screen-based military specific shoot / don't-shoot task that involves responding to

24 targets equally distributed across 12 windows in a two-story warehouse. Five randomised conditions included a no information condition, two location-based conditions where prior intelligence suggested 66% of the targets were either on the first or ground floor, and two threat-related conditions prior intelligence suggested 66% of the targets were either hostile or non-hostile. Measures included response time and accuracy, a speed accuracy trade off, and measures of cursor position. **Results:** Significant main effects of group were observed where the gaming group outperformed the control group's response accuracy ($F_{4,42}$ = 4.238, p = 0.046, η_p^2 = 0.026) and response time ($F_{1,42}$ = 21.210, p < 0.001, η_p^2 = 0.341) resulting in a larger difference in speed accuracy trade off ($F_{4,42}$ = 22.052, p < 0.001, η_p^2 = 0.350). There were no effects of condition or interactions for the performance variables (all p > 0.05). However, condition did have a significant effect on the cursor position ($F_{4,168}$ = 4.229, p = 0.003, η_p^2 = 0.091) where both groups responded to location-based context by moving the cursor higher in the first-floor condition. **Conclusions:** Experience in gaming influenced performance of a military-specific shoot / don't-shoot task. Performance was not affected by probabilistic information, but location-based information did induce a bias in the aiming point for both groups. **Military Impact:** Familiarity with military specific shoot / don't-shoot tasks may lead to enhancement in performance. However, probabilistic information about the environment may not improve performance and could lead to unfavourable biases in aiming. Plausibly probabilistic information should be avoided where high degrees of certainty are not possible.

Board 32: Unregulated caffeine consumption and the cognitive performance of Israeli Infantry Special Forces trainees during a 96-hour field combat exercise

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Purpose: Advanced training for Israel Defense Forces (IDF) Special Forces (SF) culminates in a rigorous 96-h combat exercise under conditions of sleep deprivation. Although caffeine can benefit performance under fatigue conditions, the IDF does not currently provide guidelines for caffeine consumption during military duties. The aim of the study was to evaluate the cognitive performance, mood states, and propensity for risky behaviors during the combat training exercise under conditions of sleep deprivation. **Methods:** Twenty-eight male SF soldiers (20.6 ± 0.9 y) were monitored by Actigraph for activity and sleep over 96 h. The Psychomotor Vigilance Test (PVT) evaluated cognitive performance. Questionnaires assessed the Profile of Mood States (POMS), Evaluation of Risks Scale (EVAR), and caffeine intake (high caffeine consumption defined as ≥ 200 mg). Data were collected at baseline 0, 50, and 96 h. **Results:** Participants hiked 109 ± 2 km and slept a total of 12.7 ± 0.5 h. During the first 50 h of the exercise, participants slept 7.5 ± 0.3 h in multiple sleep periods. From 50 h until the completion of the exercise, participants slept 5.2 ± 0.3 h in a single sleeping period. All participants voluntarily consumed caffeine at least once, with the highest single dose being 1,000 mg (14.6 mg·kg bm^{-1}). Significant changes were noted in mean reaction time (MRT) on the PVT (p < 0.002) (between 0-50 h and 0-96 h). The POMS score decreased from 117.5 to 95.7 (p < 0.001) between 50-96 h. Participants

who consumed ≥ 200 mg of caffeine at 50 h showed a significant improvement in PVT-MRT (0.31 s *vs* 0.35 s, $p < 0.05$), and the EVAR score was 10.1% higher ($p < 0.05$) compared with those who consumed < 200 mg of caffeine. **Conclusions:** Sleep deprivation negatively impacted cognitive performance (PVT-MRT). A single 5-h sleep period positively impacted cognitive performance (PVT) and mood states (POMS) more than multiple shorter periods of sleep. While caffeine improved PVT-MRT at the 50-h mark, it did not prevent increased risk-taking behavior. **Military Impact:** Regulated caffeine consumption can offer operational benefits under fatigue conditions, but unregulated consumption is unlikely to achieve these advantages reliably. Furthermore, acute caffeine intakes exceeding 400 mg can be harmful. Therefore, it is necessary to implement guidelines for caffeine consumption to achieve operational benefits and prevent misuse and harm.

Board 33: The Effect of rotary shifts on the cognitive performance of Israeli Submariners: preliminary results

Itay Ketko [1], Daniel S Moran [2], Ido Baum [1], Nadav Refael [3], David Erez [2]

[1]The Institute of Military Physiology, IDF Medical Corps
[2]Ariel University, Israel

Purpose: The Israeli Navy currently uses rotary shifts of 3- and 4-h duration over a 20-h watch bill. Circadian misalignment has shown to affect alertness, sleep quality, and cognitive performance, which may harm submarine team performance. The present study aimed to monitor the sleep and wakefulness patterns, cognitive function, mood, and willingness to take risks of submariners during routine rotating shift work on a five day at sea mission. **Methods:** Twenty-five male submariners from a submarine crew were recruited to this study (22 ± 2 y). Sleep patterns and physical activity (wrist-worn ActiGraphTM monitors), cognitive performance (Psychomotor Vigilance Test, PVT), the profile of mood states (POMS), and perception of risk propensity (Evaluation of Risks Scale, EVAR), were assessed before, during, and on completion of the mission. **Results:** The participants slept 8.3 ± 0.2 h per 24 h. Although the current watch-bill schedule provides an 8-h sleep opportunity between shifts, the submariners used less than 4-h for consecutive sleep between shifts (3.7 ± 0.8 h). Cognitive tests showed decreasing trends in anger, depression, and vigour on subscales of POMS, while impulsiveness and invincibility increased on the EVAR subscales. In addition, the number of PVT premature responses and time-outs increased while the number of valid answers decreased over the course of five days. When data were divided by watch-group, markers for mood states and perception of risk propensity oscillated asynchronously with the rotating watch-bill. The observed trends in the interim results suggest that the current rotating watch bill impacted performance over time. Based on the questionnaires, the submariners became less depressed and vigorous but more impulsive, invincible, impatient, and made more mistakes. **Conclusions:** The negative impact on PVT (timeout and premature response) over time is likely due to a combination of daily circadian misalignment (due to the 20 h watch bill) and fatigue from the monotony of the daily routine. However, the mood states (anger, depression, and vigour) appear to improve over the same period. This could be explained by adopting an introverted attitude. The increase in the willingness

to take risks (EVAR: impulsiveness and invincibility) over time is consistent with the increase in fatigue, as previously described. **Military Impact:** Our study points out the importance of proposing an adjusted watch bill to attempt to minimise the impact on performance. This may be achieved by implementing a fixed schedule of daily work and sleep period opportunities for each watch group based on a 24-hour schedule while scheduling shorter night shifts. Special attention must also be given to the effects of pre-mission fatigue, particularly on the first night of the at sea mission. Due to the submariners' unique physiological and cognitive challenges, further research is needed to develop strategies to alleviate the effects of rotary shifts and sleep deprivation on cognitive performance.

Board 35: Effects of heat stress in armoured vehicles on cognitive performance and their mitigation due to individual cooling: preliminary results of a pilot study

Alexander Witzki [1], Maria Richter [1], Manuela Andrea Hoffmann [1]

[1]Bundeswehr Institute for Preventive Medicine, Germany

Purpose: Significant heat stress can occur in armoured vehicles and lead to a sizeable increase in body temperature. This effect can be reduced by use of individual air-cooling vests. The aim of this pilot study was to determine effects of heat stress and individual cooling on cognitive performance. **Methods:** In a within-subject design, participants were exposed to desert climate conditions (air temperature: 44°C, relative humidity: 20%) with and without a cooling vest according to a protocol simulating heat stress during a patrol in an armoured vehicle (phase I: 1.5 h sitting in a vehicle, phase II: 0.5 h patrolling on foot at 3 $km \cdot h^{-1}$, phase III: 0.5 h sitting in a vehicle, phase IV: 0.5 h patrolling on foot at 3 $km \cdot h^{-1}$, phase V: 0.5 h sitting in a vehicle). Cognitive tests of concentration (Test for Measurement of Executive Control / Concentration; TEMEKKO), short term memory (Digit Span Forward), and working memory (Digit Span Backward) were conducted immediately before and 60 min after as well as during phase V of heat expose. Data of six soldiers were available for analyses. **Results:** Inferential statistical analyses were not feasible due to small number of participants. Descriptive data indicate a positive effect of heat exposure on concentration and a performance decrement in short-term memory. Both effects are mitigated by cooling. The result pattern of working memory performance is inconclusive. **Conclusions:** Heat stress in armoured vehicles affects cognitive performance, but these effects may be mitigated by direct cooling of Soldiers via air-flow cooling vests. **Military Impact:** This approach has the potential to preserve cognitive readiness of military personnel during prolonged heat exposure in armoured vehicles.

Board 36: Exploring relationships between fireteam communication and marksmanship performance across varying engagement workload conditions

Peioneti Lam [1], Michael King [2], John J Christopher [3], Jose D Villa [1], Stephanie AT Brown [1], Seth ElkinFrankston [1], Victoria G Bode [1], Katherine Mitchell [1]

[1]U.S. Army Combat Capabilities Development Command Soldier Center, USA
[2]Quantum Improvements Consulting, USA

[3]U.S. Army Aberdeen Test Center, USA

Purpose: Enhancing team lethality remains a priority for the U.S. Army. Current technological and training enhancements that seek to improve team lethality are reliant upon improving a team's ability to communicate and coordinate lethal action. However, a gap exists in understanding possible trade-offs between the two in an operationally realistic task environment. This study investigated relationships between communication and team marksmanship performance in a simulated team shooting scenario as part of a 72-hour field study. **Methods:** Twenty teams of three Infantry Soldiers (all male) completed a simulated, rapidly escalating six-minute firing engagement where task workload, or density of active targets per soldier's sector of fire, varied across six segments of the engagement. Teams were instructed to coordinate, detect, and engage targets surrounding them in a 7.5 m radius, while watching for friendly targets. Communication metrics were gathered from audio recorders attached to each Soldier, including target callouts, offering help, etc. Marksmanship performance metrics of probability of hit and percent of targets engaged were gathered from the weapon-sensor suite and target system. Across each segment of the scenario, Spearman's rank correlations were computed to assess the relationships between quantities of task-relevant team communications and team marksmanship performance metrics. **Results:** No statistically significant correlations were found between communication quantities and team marksmanship performance metrics in low or moderate workload mission segments. A strong positive correlation ($r_s(18) = 0.67$, $p < 0.001$), was found between target callout counts and percent of targets engaged in the man-down segment (high workload) of the scenario and a moderate negative correlation ($r_s(18) = -0.57$, $p = 0.009$) was found between total word count and probability of hit during the roving-target (high workload) segment of the engagement. **Conclusions:** Fireteam marksmanship performance was primarily related to teams' communication in high task workload engagements, however, the relationship between communication and marksmanship was not always positive. In man-downed engagements, target callouts were positively associated with the percent of targets the team engaged. However, in engagements where task demands are disproportionately placed on one individual, of which the other teammates may be unaware of, total communication was found to be negatively related to the team's probability of hitting targets. Further analysis is needed to understand this association. **Military Impact:** This study provides initial evidence that communication training may improve fireteams' situational understanding, target detection, and engagement.

Board 37: Measuring the effects of concurrent and subsequent physical activity on cognitive performance by using the Load Effects Assessment Program (LEAP) obstacle environment

Olaf Binsch [1], Annemarie Landman [1], Lotte Linssen [1], Jikke Reinten [1], Koen Hogenelst [1]

[1]Netherlands Organization for Applied Scientific Research, The Netherlands

Purpose: Dismounted soldiers often need to perform physical and cognitive tasks concurrently and / or sequentially. Previous research on the effects of concurrent and subsequent physical activity on cognitive performance has focused on physical activities with little complexity and variation, such as treadmill running and cycling. However, physical activities of infantry units often vary in complexity and intensity, especially in urban settings. **Methods:** In this pilot study, soldiers (n = 10) individually ran the varied Load Effects Assessment Program (LEAP) obstacle course while conducting cognitive tasks (N-back, Mackworth clock detection task, or self-reports) compared with cognitive performance measured during more simple physical activity (*i.e.*, running on a flat and obstacle-free terrain) and to no physical activity (*i.e.*, sitting). **Results:** The current pilot study showed that cognitive performance (N-back misses) during physical activity was most affected by the LEAP condition, less by the running condition, and least by the sitting condition, confirming cognitive-energetic theories. Considering the low number of participants and statistical power, the differences between the conditions were statistically significant and the effect sizes were large ($r > 0.85$). Self-reported mental effort was only significantly higher in the physically active conditions compared with sitting, also with a large effect size ($r > 0.85$). Cognitive performance (N-back misses) subsequent to physical activity were only significantly different between the physically active conditions and sitting, with large effect sizes, ($r > 0.80$) confirming arousal theories. The subjective mental effort indicated the same pattern in differences between conditions ($Z = 2.80$, $p = 0.005$). The cognitive Mackworth clock detection task revealed only a significant difference between the LEAP condition and sitting, perhaps indicating that the LEAP condition had a more pronounced positive effect ($Z = 2.68$, $p = 0.007$, $r = 0.85$). **Conclusions:** The results indicate that concurrent performance of cognitive tasks and intense or complex physical tasks should be avoided, if possible, when required to perform cognitively. In addition, sequencing cognitive tasks directly after physical activity could possibly be used to enhance cognitive performance. **Military Impact:** Sequencing physical activity in a specific order can have a positive impact on cognitive performance in military personnel. The LEAP obstacle environment is able to simulate complex urban terrain, thereby offering the opportunity to moderate physical activity to improve cognitive performance. Hence, the LEAP course might also a platform to evaluate the effect of physical activity as human augmentation technology.

Board 38: Understanding the impact of mental fatigue: competitive orienteering as a model for mental fatigue studies in military personnel

Hui Kwan Nicholas Lam [1], John Sproule [1], Anthony P Turner [1], Shaun M Phillips [1]

[1]The University of Edinburgh, UK

Purpose: The presence of mental fatigue (MF) has been demonstrated to have a detrimental effect on a variety of cognitive tasks associated with human performance in the military. Previous research also indicated that MF can impair reaction time, endurance, and decision-making performance in sport. Orienteering involves running through an unknown terrain whilst using a map and compass to reach the next checkpoint within a specified time limit, requiring athletes to endure both physical and cognitive fatigue. As some fundamental skills of soldiers and orienteers are similar, orienteers were chosen as a model to determine if those regularly exposed to a high physical and cognitive load environment are affected by MF. The aim of this study was to assess whether MF affects orienteers during training camps. **Methods:** Ten

national junior orienteers participated in the study (age: 15 to 17 y, height: 1.69 ± 0.10 m, body mass: 59.9 ± 5.3 kg). They completed a 4-day simulated orienteering race which incorporated sprint, middle-distance, long-distance, relay, and night orienteering. Ratings of perceived MF and physical fatigue (PF) were measured with a 0 to 100 visual analogue scale. Measurements were taken within 30 minutes of waking, immediately after each training session, and one and two days after the completion of the training camp. Data was analysed using the mean difference and magnitude of changes. Data were presented as effect size [95%CI]. **Results:** There was a moderate to very large change in MF before and after each training session (Day 1: d = 1.29 [0.16 , 2.37]; Day 2: d = 0.85 [0.03, 1.64]; Day 3: d = 1.06 [0.26, 1.83]; Day 4: d = 1.00 [0.35, 1.62]) with 48 h post presenting a moderate increase from the pre-training value (d = 0.67 [–0.22 , 1.54]). A similar trend was observed in PF but with a trivial to moderate difference between PF and MF. **Conclusions:** This research concludes that both MF and PF increased and accumulated during a 4-day training camp and did not return to pre-training levels 48 hours after the camp. This research demonstrates that even those who are physically and mentally trained can still experience MF from training. **Military Impact:** It is feasible that military personnel may suffer from MF due to their training, and the inability to recover swiftly from the increased MF could potentially lead to a further decline in their judgement accuracy following a long period of training if there are no suitable strategies in place to manage the MF.

Board 39: Feasibility and methodology of neurofeedback training to optimise attentional performances of healthy soldiers

Clémentine Jacques [1] , Michael Quiquempoix [1,2], Fabien Sauvet [1,2], Damien Léger [1], Michel Le Van Quyen [3], Danielle Gomez-Merino [1,2], Mounir Chennaoui [2]

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Purpose: The military operational environment affects the safety of soldiers and their decision-making efficiency. It is therefore necessary to be adaptable and flexible in the face of adversity. Just like physical performance, it is possible to use brain training programs such as neurofeedback protocols to improve cognitive performance (*e.g.*, attention, working memory, decision-making). We set up a methodological approach to study the effects of electroencephalogram alpha neurofeedback training (EEG-alpha-NFB training) on attentional performances of healthy soldiers. **Methods:** A total of eight healthy men and women (aged 20 to 42 y), performed two cognitive tests over 5 consecutive days: the Attentional Network Test (ANT) and the AX Continuous Performance Test (AX-CPT). Learning effects on cognitive tests were evaluated using respectively a one-way repeated measures ANOVA reaction time [RT] over the five sessions and effect sizes. In addition, three participants performed five consecutive days EEG-NFB training with an in-lab developed brain-computer interface reproducing a cockpit of the RAFALE military aircraft and were recorded for an EEG resting-state period (2 min eyes opened and eyes closed) before (T1) and after (T2) NFB-training. The trained EEG-NFB parameter was the individual alpha frequency, which is linked to attentional performances. Each session lasted 35 min (10 blocks of 3 min with short breaks of 30 s) and the effect of EEG-alpha-NFB training were evaluated using a linear regression. **Results:** We observed no session effects on response time during the AX-CPT ($F = 0.884$, $p = 0.494$) and no session effect on the conflict monitoring score obtained during the ANT ($F = 1.69$, $p = 0.198$). Moreover, for one "responder", we reported a positive learning curve of the trained EEG-NFB parameter during NFB-training, with a tendency to increase during resting-state (each day, at T1 [$r = 0.065$ and $p = 0.233$], and T2 [$r = 0.839$ and $p = 0.076$]). Conversely, a "non-responder" had a negative learning curve as does the participant performing the placebo training. For these latter participants, the EEG parameter did not increase during resting-state (T1 [$r = 0.500$ and $p = 0.391$], and T2 [$r = 0.114$ and $p = 0.855$] and T1 [$r = 0.205$ and $p = 0.741$], and T2 [$r = 0.473$ and $p = 0.421$]). **Conclusions:** We developed an experimental paradigm to study attentional performances in the context of neurofeedback training based on a brain-computer interface simulating the cockpit environment of a pilot. **Military Impact:** Development of a brain-computer interface based cerebral training could improve soldier's attentional performances in operational contexts.

Board 40: The relationship between marksmanship qualification scores and a simulated marksmanship performance task

Jose D Villa [1], Peioneti Lam [1], Stephanie AT Brown [1], John J Christopher [2], Linda DeSimone [1], Meghan O'Donovan [1], Clifford Hancock[1], Wade Elmore[1], Seth Elkin-Frankston [1], Victoria G Bode [1], K Blake Mitchell [1]

[1]US Army Combat Capabilities Development Command Soldier Center, USA
[2]US Army Aberdeen Test Center, USA

Purpose: The U.S. Army recently updated the guidance used by military leaders to conduct marksmanship training. As part of this update, a more operationally realistic qualification test was developed to assess marksmanship proficiency. The new test simulates combat engagements with multiple target presentations at once and limited exposure time to induce a more realistic level of battlefield stress. **Methods:** 67 male, active-duty Infantry U.S. Army soldiers (age: 23.8 ± 3.6 y; years in service: 3.1 ± 2.7 y) completed a simulated marksmanship individual shooting scenario (ISS) task comprised of static and dynamic engagements. The ISS task assesses the entire marksmanship process of moving, positioning, and engaging targets. Self-reported qualification scores from the new marksmanship qualification test were gathered from demographic questionnaires. Spearman's rank-order correlations were run to assess the relationship between soldiers' marksmanship qualification scores and ISS performance measures. **Results:** There were significant correlations with qualification score, including weak, positive correlations with the lethality measures of static probability of hit ($r_s(64) = 0.317$, $p < 0.001$), static probability of lethal hit ($r_s(64) = 0.314$, $p = 0.01$), and dynamic enemy-friendly discrimination engagements ($r_s(64) = 0.330$, $p < 0.01$). Significant correlations were also found with stability measures, including a weak, negative correlation with static trigger control ($r_s(64) = -0.261$, $p < 0.05$) (lower trigger control scores indicate better performance) and a weak, positive correlation with reduced dynamic horizontal stability ($r_s(64) = 0.243$, $p < 0.05$). **Conclusions:** Results indicate that higher scores in the new marksmanship qualification test are associated

with an increased probability of hitting targets and making centre-of-mass hits, as well as with a greater ability to discriminate between enemy and friendly targets. Higher qualification scores were also associated with better trigger control and lower horizontal stability. However, this may be due to the ISS's design, since participants were tasked with quickly scanning left and right between multiple target engagements. A larger sample size and follow-on analysis are required to validate these relationships further. **Military Impact:** Marksmanship qualification scores are an important tool for military leadership to measure the readiness and effectiveness of soldiers. Results from this analysis provide initial evidence that the U.S. Army's new qualification test can be a good assessment of holistic marksmanship performance beyond just hits on target.

Posters 3: Psychological Resilience and Performance

Thursday 14th September, 12:15 to 13:45

Board 41: The mental preparation of the Military and Sports Physical Training Instructors (SPTI) in formation

Gilles Fégueux [1], Christine Le Scanff [2]

[1]Ministry of the Armed Forces, France
[2]Ministry of Higher Education and Research, France

Purpose: The purpose of mental preparation for the soldier is to improve operational efficiency, mental resistance to effort, and manage their state of fatigue. The objective of this project is to investigate whether the implementation of a mental preparation programme, using the ORFA (Optimization of the Resources of the Armed Forces), has a beneficial effect on the success of the physical and intellectual evaluations of the monitor EPMS (Physical Training Military and Sportsman: military physical trainer) and the management of state of fatigue during training. **Methods:** Eighty-five military trainees (79 men and 6 women, aged 19 to 41 y) completing the EPMS monitor course volunteered to take part in the study. The main criterion is to apply the same mental preparation with ORFA to the entire group for equity between the trainees, because the results obtained determine their choice of assignment in different military units at the end of the training period. Five questionnaires on the physical and mental state of the individual were completed (POMS, State of anxiety, State of Spielberger, STAI 1 and 2, PANAS and well-being) to track the evolution of training workload, the management of the fatigue, the physical and psychological feelings during training, and the application of mental preparation. The statistical analysis determined the variance of each of the five tests of physical and psychological feeling by accumulating the results for each section to obtain an overall result for the 85 participants. The statistical analysis allowed identification of the evolution of the variance of the feeling of the physical and psychological state during the seven measurement times throughout the training. The goal is to know the positive or negative evolution of the psychological and physical feelings of the EPMS instructors in training. The POMS questionnaire led to an irregular range of scores and T-scores were used to better illustrate the results and then an analysis of the variance of the means to see the evolution of mood. **Results:** During the two main periods of stress linked to the challenge of passing three exams, the mental preparation work allowed the trainees to approach the deadlines more positively. High positive values on the PANAS test may explain the benefits of mental preparation. By comparing the results of the last two promotions, the average of the trainees' marks has increased by 0.5 points. Success in the course increased for the EPMS instructor diploma (+10%) and the number of injured decreased (−15%). **Conclusions:** The statistical study shows a correlation between the evolution of the physical and mental state and the increase of the trainees' success. **Military Impact:** The new techniques of mental preparation (ORFA) contribute to the preparation and the mental recovery of the soldier.

Board 42: Sustainable physical and mental readiness training for tactical operators

Richard Cleveland [1], Bridget Melton [1], Joseph Dulla [1], Nicholas Hunt [1]

[1]Georgia Southern University Tactical Athlete Initiative, USA

Purpose: Physical/mental readiness continue to receive separate and often unequal training for tactical operators. Often, limited resources are primarily dedicated to outdated physical conditioning practices, while mental resilience may only be offered as a one-time lecture presentation. While attention to musculoskeletal injuries has shed light on physical training, limited attention has focused on mental preparedness, which may create a false sense of security regarding mental health readiness. Additionally, readiness efforts in initial training may not continue throughout the operator's career. This disadvantages operators and creates liability for physical injury and mental health / post-traumatic stress injury (PTSI). **Methods:** Researchers partnered with law enforcement/fire service agency initial training programs to develop and implement a comprehensive physical readiness training program with elements of mental resilience embedded in domain-specific activities. The program was disseminated through a 16-hour train-the-trainer program. Impact of the program was evaluated via cadet evaluation. 390 law enforcement graduating cadets (age 28.5 ± 8.1 y; 84.1% male, 14.3% female) from eight training centres completed an online survey between September and December 2022. The survey measured self-reported perception of training intensity, engagement in training activities outside of academy, and intention to continue training activities after academy completion. Statistical analyses utilised t-test, ANOVA, and Pearson correlation methodologies. **Results:** Participants responded positively to the training program, with 85% reporting likely to continue the training into their careers. A negative correlation was demonstrated ($r = -0.34$) between the intention to continue "traditional" training activities (i.e., formation run). A slight majority (57.8%) of participants reported not practicing mindfulness-resilience activities outside of training; however, those who did report practicing mindfulness outside of formal training demonstrated a statistically significant difference in intention to continue mindful-resilience practices into their career (*i.e.*, post-academy). **Conclusions:** Results from the present study encourage revisions to tactical operator readiness training. Comprehensive programs that integrally link physical / mental resilience not only better prepare operators for diverse, asymmetric environments, but also provide a foundation of wellness guarding against physical and mental injury resulting from the hazardous stressors that inhabit tactical work. **Military Impact:** The present study collaborated with United States law enforcement / fire service tactical operators, however, the implications for military / defence populations are relevant. With declining recruitment and increased physical / mental stressors, operator readiness and sustainability remain a critical concern. A comprehensive readiness program such as the one presented in this research provides an innovative solution covering both preventative and responsive / remedial needs.

Board 43: An ecological approach to clinically assess nightmares in military service members with severe PTSD

Emeric Saguin [1], Dorone Feingold [2], Danielle Gomez-Merino [2], Mounir Chennaoui [2]

[1]Begin Military Teaching Hospital, France
[2]Vigilance Fatigue Sommeil et Santé Publique, France

Purpose: Trauma-related nightmares (TRNs) are distressing events that contribute to the severity of insomnia, and the chronicity and treatment resistance of PTSD. TRNs are difficult to record during a single night in a sleep laboratory, which is likely to be viewed by patients as a protective sleep environment, not representative of home sleep conditions. This study investigated whether objective sleep measurements obtained at home using wearable electronic devices had clinical value in correlating PTSD patients' complaints about sleep and nightmares. Secondary objectives were to correlate awakenings associated with TRNs to sleep stages, and to provide new insights on the use of electrodermal activity (EDA) as a potential physiological marker of TRNs. **Methods:** Over a two-year inclusion period, sixty veterans and active-duty service members were assessed by mental health and sleep questionnaires (PCL-S, PSQI, ISI, TRNS-FR and Berlin questionnaire) and recorded for 5 consecutive nights at home using the Dreem Headband® for sleep stage classification and the Empatica E4® for physiological measurements (push-button to signal TRNs and EDA). Correlation analyses and ANOVA were performed. **Results:** Of the 60 patients included in our study, we retained 245 nights recorded by 57 patients (54 men and 3 women). A synchronization method between the two devices—based on heart rate (HR)—was developed which allowed us to match 200 TRNs (reported by the event marker push button) with sleep phases corresponding to 91 nights and 37 patients. Most awakenings associated with TRNs occurred during NREM sleep (65.5% vs 34.5% during REM sleep). Our results also revealed significant differences in the frequency of EDA peaks 10 min before the reported events, with a lower frequency in REM (13.7 peaks) than in NREM (24.8 peaks) awakenings associated with TRNs. Importantly, positive correlations were identified between subjective and objective sleep parameters (total sleep time, sleep-onset latency, and TRNs frequency). **Conclusions:** Our study demonstrated, in a large number of patients with severe PTSD, the value of high-quality, low-cost home monitoring of nightmares and sleep, using two wearable devices. Several recorded sleep characteristics (TST, SOL) and awakenings associated with TRN events (frequency of occurrence) were significantly correlated with patients' subjective complaints, and we also confirmed that awakenings associated with TRNs occurred both in REM and NREM sleep. **Military Impact:** This methodology paves the way for studies on the links between nightmare and sleep in the clinical follow-up of military patients with severe PTSD, using wearable electronic devices under ecological conditions.

Board 44: The relationship between frequency of psychological skills application and novices' shooting performance in the military

Rachel Chan Sihui [1] , Christie Sze Yi Han [1]

[1]Singapore Armed Forces, Singapore

Purpose: Training soldiers to apply psychological skills has been found to be effective in helping them cope better with various military stressors and enhance their resilience and other psychological outcomes. This study investigates the relationship between frequency of psychological skills application (PSA) and novice shooters' performance, resilience, and stress perception. Shooting was selected because shooting score is an objective indicator of individual soldier performance. **Methods:** Ninety-five trainees from a three-month security and policing course in the Singapore Armed Forces participated in the study. A live firing exercise was conducted in week 6 where trainees were first trained to fire a pistol. Before the

course, trainers were taught the concepts of psychological preparation and how psychological skills (i.e., goal setting, cognitive reframing, combat breathing, and visualisation) could help enhance performance and they reinforced these during lessons with their trainees. Trainees were also introduced to the same concepts in week 1. Before the exercise, trainers led trainees through a guided visualisation and reiterated the importance of applying the psychological skills learnt. Trainees completed two surveys (pre- and post-exercise) to report their stress and confidence levels, resilience, and frequency of PSA. Bivariate correlation analyses and t-tests were used in data analysis. **Results:** Trainees' frequency of PSA was positively correlated with state resilience at pre-exercise ($r = 0.405$, $p < 0.001$). Trainees with higher frequency of PSA had higher shooting scores ($r = 0.250$, $p = 0.014$). A median split and independent samples t-test revealed that trainees with higher frequency of PSA performed approximately 10% better than those who did not use the skills as frequently ($t(93) = -2.30$, $p = 0.024$). Interestingly, trainees reported elevated stress levels from pre-exercise to post-exercise ($t(94) = -2.21$, $p = 0.029$). **Conclusions:** Findings support that frequency of PSA enhances soldiers' performance and resilience. Trainees reporting elevated stress levels post-exercise could be related to their recollection of their first live firing experience, which may have generated feelings of stress and anxiety. This suggests that beyond applying psychological skills to enhance mental preparation pre-performance, it is important to help trainees reflect constructively and assimilate lessons learnt to further build their confidence and resilience post-performance. **Military Impact:** Military training is inherently stressful, but it provides valuable opportunities for personal growth. Equipping soldiers with psychological skills pre-training coupled with post-training debriefs could further enhance their mental and physical readiness to cope with stress and perform effectively.

Board 45: Dynamic associations between catastrophic thinking and PTSD among active-duty military personnel receiving cognitive processing therapy

Sarah Vacek [1], Kaitlin Grelle [1], Kara Rayha [1], Willie Hale [1]

[1]University of Texas at San Antonio, USA

Catastrophic thinking and posttraumatic stress disorder (PTSD) symptoms have been associated both cross-sectionally and longitudinally; however, further research is needed to determine whether and exactly how cognitive change precedes and predicts symptom change, particularly within samples receiving evidence-based treatments for PTSD. This study examined the degree to which weekly changes in catastrophic thinking predicted subsequent changes in PTSD symptoms (and vice versa) over the course of cognitive processing therapy (CPT). Participants were 321 active-duty U.S. Army soldiers with PTSD who received CPT in one of two clinical trials. On average, participants were 33 years old and were primarily male (91%), with the majority serving as members of the enlisted ranks (97%). PTSD symptom severity and catastrophic thinking were assessed at baseline and weekly over the course of treatment. Dynamic temporal sequential dependencies between the constructs were examined using the change-on-change extension of the bivariate latent difference score model. **Results:** Consistent with our main prediction and the theory underlying CPT, results show that earlier changes in catastrophic thinking predicted subsequent changes in PTSD total scores. Specifically, changes in PTSD Check List (PCL-S) total scores were the sum of two separate components: first, the constant linear decrease in PTSD symptoms (C[PCL-S] = −1.39, $p < 0.001$), which represents a direct effect of treatment on overall PTSD symptoms, and second, the indirect effect of prior changes in catastrophic thinking (D[C*P] = 1.23, $p = 0.038$). That the latter effect was significant provides strong evidence that directly reducing catastrophic thinking results in downstream reductions in PTSD severity, supporting the theory underlying CPT that changes in cognition drive PTSD symptom change. This interpretation is strengthened by our finding that the converse effect, that of earlier changes in PTSD on subsequent changes in catastrophic thinking, was not significant. At the subscale level, the pattern of results was most similar when modelling re-experiencing symptoms (CFI = 0.95, RMSEA [90% CI] = 0.07 [0.06 - 0.08]). **Conclusions:** The present study's findings show a unidirectional effect of changes in catastrophising cognitions on PTSD symptoms over time. Overall, the present study's findings highlight the importance of addressing catastrophic thinking in CPT, given that changes in catastrophic thinking preceded and predicted subsequent changes in PTSD symptoms (especially re-experiencing symptoms) and not vice versa. **Military Impact:** These findings improve our understanding of the mechanisms of CPT when treating PTSD, providing support for the underlying theory of this therapy within military populations.

Keynote 4

Thursday 14th September, 14:00 to 14:45

Main Room

Major General Tim Hodgetts
CB CBE KHS DL OStJ PhD MMEd MBA MBBS CMgr FRCP FRCSEd FRCEM FIMCRCSEd FRGS

Surgeon General, UK Armed Forces

Tim was commissioned in 1983 and trained at Westminster Medical School, qualifying with distinction in 1986. He holds fellowships with the Royal College of Physicians of London, Royal College of Surgeons of Edinburgh, Royal College of Emergency Medicine, Faculty of Pre-hospital Care, Institute of Healthcare Managers, and the Royal Geographical Society. He has a PhD in Public Health ('A revolutionary approach to improving combat casualty care'); Master's degrees in Medical Education and Business Administration; and is a Chartered Manager. He graduated from Joint Command & Staff College (psc[j]) in 2011 and the Royal College of Defence Studies in 2018.

Tim's professional career began as a general physician in the British Military Hospital in Hannover, progressing to higher training in emergency medicine in Manchester and Sydney. He became Consultant in Emergency Medicine at Frimley Park Hospital from 1995, transferring to the Royal Centre for Defence Medicine in 2001 on its inception, where he served until 2010. He was first appointed a Professor in 1998 at the European Institute of Health and Medical Sciences, then at the University of Birmingham (2001), and at City University of London (2013). He was the inaugural Defence Professor with the Royal College of Emergency Medicine, and Penman Foundation Professor of Surgery in South Africa for 2011.

Within Defence Tim has been responsible for nurturing the specialty of emergency medicine from infancy to maturity. He has implemented concept, doctrine, equipment and practice changes to transform the early management of combat injury and led major trauma governance from 1997-2010. Clinical leadership appointments have included Defence Consultant Adviser in EM (1997-2008); and Assistant Director Clinical Services at RCDM (2001-2007). He has served on operations in hospitals in Northern Ireland, Kosovo, Oman, Afghanistan (3 tours), Kuwait and Iraq (4 tours). On 6 of these tours, he was the hospital's Medical Director, including the multinational Danish-UK-US hospital in Afghanistan, 2009. From 2011-13 he was Medical Director within NATO's Allied Rapid Reaction Corps; and from 2014-17 he was Medical Director for the Defence Medical Services. From 2018 until assuming his role as Surgeon General he has was the Army's Senior Health Advisor, the Head of the Army Medical Services and a Commissioner at the Royal Hospital Chelsea.

Tim has published extensively (books & journal articles) and regularly lectures internationally as a keynote speaker on leadership, innovation at pace, disaster medicine and combat casualty care. He is co-author of Major Incident Medical Management and Support; Battlefield Casualty Drills; Army Team Medic; Battlefield Advanced Trauma Life Support; and Clinical Guidelines for Operations. He co-founded the citizenAID® charity from 2017, designing a free multi award-winning app to support the public during a terrorist attack and inventing a new device (the Tourni-Key™) for the public to treat life-threatening limb bleeding.

Tim was made Officer of the Order of St John of Jerusalem in 1999 and Commander of the British Empire in 2009; he received the Danish Defence Medal for Meritorious Service in 2010. He was Queen's Honorary Physician from 2004 to 2010 and became Queen's Honorary Surgeon in 2018. In 2010 he received the Defence Scientific Adviser's Commendation for contribution to research and has been awarded 18 academic medals, including the prestigious Mitchiner Medal of the Royal College of Surgeons of England. His academic department was twice recognised nationally as the "Training Team of the Year" and in 2006 he was honoured with the personal accolade of Hospital Doctor of the Year throughout the NHS. He was named in a British Medical Association dossier as one of the most innovative doctors in the country.

Thematic Sessions 28 to 30

Thursday 14th September, 15:15 to 16:45

Thematic 28: Holistically assessing dismounted infantry performance: bridging science and operational relevancy

Main Room

Description

Dismounted warfighter performance is multi-faceted and involves many interdependent domains including mobility, lethality, survivability, and sustainability. In recent years, various aspects of dismounted performance have been directly measured in the field to better understand the impact of novel technologies on performance, training, readiness status, or return to duty after an injury. To date, scientific approaches have necessarily focused on singular or limited metrics of performance. While a single outcome is informative, the nature of dismounted performance is inherently multi-factorial and single metrics likely miss key aspects of performance. The greatest return on investment and informative measures and analysis should attempt to assess and analyse several metrics of dismounted performance to better capture the complexities and interdependencies. This session will focus on recent efforts to quantify the multi-variate aspects of dismounted performance and future directions to assess warfighter performance holistically and objectively both at the individual soldier and squad levels.

Background

Dismounted warfighter performance is inherently multifaceted and complex. Mobility, lethality, and survivability are all of interest to better understand, for example, operational readiness, impact of novel or new kit or technology, or return to duty after an injury. Recent advances in wearable sensors, onboard data storage, and extended sensor battery life, allow for measurements in a field environment that were previously limited to a laboratory or highly controlled (operationally unrealistic) field settings. Historically, field data collections have focused on single metrics or aspects of a mission task. While informative, focusing on one metric rather than the multi-faceted component of dismounted performance likely provides an incomplete or misinformed outcome. Objectively measuring and quantifying metrics across multiple domains and the interactions between these metrics provides a more complete, holistic analysis of overall mission performance and operational effectiveness to better inform training, acquisition, or return to duty.

Military Impact

This session will provide insights to military experts on comprehensively assessing dismounted infantry performance using multiple variables to scientifically inform acquisition, readiness, or training decisions. During this session, scientific experts will discuss recent efforts and emerging best practices to expand single metric field measures to multiple domains of dismounted performance. Measures of dismounted performance are frequently collected in the field to assess military readiness, areas for improvement, impact of novel or new kit or technologies, or to inform training evolutions. Objective measures, particularly when reported in operationally—and militarily relevant terms—can augment military expert observations to provide a comprehensive assessment of dismounted performance. In addition to quantifying multiple metrics, equally vital is reporting these metrics in terms that are informative, relevant, and actionable by warfighters. These topics will be presented and discussed to foster scientist and military expert interactions and collaborative approaches for future efforts.

Presentations

Chair: *Jennifer Sperlein, DEVCOM Analysis Center, USA*

15:15 – 15:27: Data driven development: quantifying operational impact of novel technology and kit on dismounted infantry performance

Jennifer Sperlein, DEVCOM Analysis Center, USA

15:27 – 15:39: Emerging results from the field: quantifying team combat performance in dismounted infantry squads

Meghan O'Donovan, DEVCOM Soldier Center, USA

15:39 – 15:51: Measuring the impact of hearing impairment and hearing protection devices on dismounted combat performance

Benjamin Sheffield, Defense Centers for Public Health – Aberdeen, USA

15:51 – 16:03: Development of a framework to profile physiological, psychological, and psychophysiological variables to predict dismounted soldier performance

Steve Myers, University of Chichester, UK

16:03 – 16:15: Wearing your heart on your sleeve (or wrist): wearable technologies for heart rate variability in the military – an update

Katrina Hinde, Defence Science and Technology Laboratory, UK

16:15 – 16:27: The implications of recent developments in motion capture and pattern recognition on collecting field data of soldier motion

Thomas Karakolis, Defence Research and Development Canada, Canada

16:27 – 16:45: Question and discussion

Thematic 29: Adopting a systems health approach to enhance warfighter readiness and resilience

Room 1

Description

This session will explore the benefits of the adoption of a 'systems approach' for: (1) increasing our understanding of the interrelatedness of the multi-domain factors influencing warfighter readiness, resilience, and performance, and; (2) influencing the process(es) by which we seek to modify and enhance these factors. The importance of this approach will be discussed across several relevant domains, including: (1) sleep timing and duration, and its downstream behavioural influence; (2) the successful integration of new technologies for multi-system, behavioural monitoring, and interventional behavioural change; (3) the challenges and requirements surrounding the implementation and adoption of emerging neurotechnology for performance enhancement, recovery, and rehabilitation, and; (4) recognition of the multi-dimensional nature of traumatic brain injury and its implications on returning to duty.

Background

To maintain and improve warfighter readiness and resilience, it is crucial to continually enhance our understanding of the independent factors that affect their health and well-being. Despite progress in knowledge and understanding, developing, coordinating, and implementing strategies based on this information remains challenging. A systems health approach acknowledges the interconnectedness of contributing factors that impact overall health and well-being. Effective implementation of this approach requires the integration of relevant components to better understand and enhance the capabilities, capacity, recovery, and performance of the warfighter. The systems health approach seeks to recognise and encompasses all interrelated factors (e.g., task, individual, community, organization, and environment) affecting warfighter's readiness and resilience. This comprehensive, systematic, and dynamic approach continuously identifies and analyses relevant factors and their interactions; defining not only how we interpret the information about these interactions and interrelated domains, but also providing a framework to generate new, advanced, deeper understanding of the phenomena.

Military Impact

Adopting a systems health approach offers several benefits for enhancing warfighter readiness and resilience: (1) the interrelated nature of the factors influencing warfighter's health and well-being (individual, task, community, organizational, and environmental) are all considered, enabling more accurate understanding of the complex interplay of these factors and their impact; (2) applicable across different scales of a problem (individual to unit level and beyond); (3) emphasises the requirement for the appropriate strategies for successful integration of all relevant factors, helping to develop both more effective understanding, and strategies for enhancing the warfighter's capabilities, recovery, and performance leading to more holistic understanding, better targeted interventions, and improved outcomes, and; (4) provides both an analytical framework and research paradigm, enabling detailed and complex appreciations of the phenomena of interest and the 'bigger picture' for the enhancement of warfighter's readiness and resilience.

Presentations

Chair: *Chris Connaboy, Rosalind Franklin University of Medicine and Science, USA.*

15:15 – 15:25: Introduction

Chris Connaboy, Rosalind Franklin University of Medicine and Science, USA

15:25 – 15:37: Assessment and categorisation of sleep health in military populations

Andrew Kubala, Naval Health Research Center, USA

15:37 – 15:49: Leveraging sleep cybernetics for performance and readiness optimisation

Anne Germain, Noctem Health, USA

15:49 – 16:01: The effect of extended morning wake times on physical, cognitive, and military-specific training outcomes in Junior Soldiers during Army Basic Training

Alex J Rawcliffe, British Army, UK

16:01 – 16:13: Observations on, and integration of, emerging neurotechnologies to improve function in the warfighter

Shawn Flanagan, University of Pittsburgh, USA

16:13 – 16:25: Traumatic brain injury is not all in the mind: understanding the implications of multiple systems to enhance return to duty time

Shawn Eagle, University of Pittsburgh, USA

16:25 – 16:45: Questions and discussion

Thematic 30: Mountain warfare: examining the effects of multi-week field training exercises in austere environments on warfighter health and readiness

Room 2

Description

The Marine Corps Mountain Warfare Training Center (MCMWTC), located in Bridgeport, California (USA), provides year-round training to military personnel preparing for conflict in austere, mountainous environments. Field training exercises are conducted at elevations from 2,100 to 3,700 meters, with temperatures between −30 to −35°C, depending on the time of year. Units perform training in steep mountainous terrain, which includes significant snow and ice during winter and spring. Research teams from the Naval Health Research Center (NHRC) recently performed a comprehensive evaluation of Marine health and readiness for two 4-week field training exercises—one occurring in fall and one in winter. This session examines the outcomes of NHRC's evaluation, with focus on warfighter physiology and health, to include thermoregulation and hydration, cognition, muscular strength and body composition, sleep, nutrition, and stress. The aim of this session is to improve understanding of the effects of mountain warfare training on warfighter health and readiness.

Background

The demands of warfare increase exponentially when performed in austere environments, such as those characterised by high-altitude, extreme temperatures, and rugged terrain. Mountain warfare training is a critical element of operational readiness for military units preparing for conflict in austere environments. Performed over several weeks, this training approach allows warfighters to experience and appreciate the very real challenges of living and operating in harsh environments. Issues related to thermoregulation and clothing systems, movement through snow and ice-covered terrain, weapon and equipment operation, water and food procurement and intake, and shelter and sleeping systems are often encountered in austere environments, and especially in the cold. The cumulative effects of such challenges in mountainous environments can negatively impact warfighters, leading to decrements in health and readiness. A critical understanding of such impacts is necessary to provide solutions and countermeasures to improve operational readiness.

Military Impact

Warfare performed in austere environments can undermine the health, readiness, and performance of individual warfighters and military units. Exposure to extreme temperatures and high-altitude, combined with heavy pack loads carried over long distances in rugged terrain, contribute to warfighter deterioration. Additionally, the hardships of living in such environments for extended durations may increase physiological and psychological stress, attenuate sleep quality, yield energy and nutrient deficits and dehydration, and reduce physiological recovery.

As such, warfighters engaged in military operations in austere environments are susceptible to injuries and illnesses, suboptimal performance, and compromised missions. A greater understanding of warfighter responses to austere environments during mountain warfare training is essential to developing effective countermeasures to improve operational readiness.

Presentations

Chair: *Douglas M Jones, Naval Health Research Center, USA*

15:15 – 15:23: Mountain warfare research overview and approach

Douglas M Jones, Naval Health Research Center, USA

15:23 – 15:31: Effects of mountain warfare training on frostbite risk and cold-weather injuries

Douglas M Jones, Naval Health Research Center, USA

15:31 – 15:43: The effects of cold-weather training on physical performance and upper and lower body muscular strength

Pinata Sessoms, Naval Health Research Center, USA

15:43 – 15:58: The influence of mountain warfare training on subjective and objective measures of sleep

Alice LaGoy, Naval Health Research Center, USA

15:58 – 16:13: Stress response in military personnel during winter mountain warfare training

Karen R Kelly, Naval Health Research Center, USA

16:13 – 16:28: Self-reported food, water, and dietary supplement consumption during mountain warfare training compared with recommendations

Lynn Cialdella-Kam, Naval Health Research Center, USA

16:28 – 16:36: Tracking attention control decrements across mountain warfare training

Timothy Dunn, Naval Health Research Center, USA

16:36 – 16:45: Assessing warfighter resilience to mountain warfare stressors using clustering analyses

Timothy Dunn, Naval Health Research Center, USA

Keynote 5

Thursday 14th September, 19:00 to 19:45

Gala Dinner

Professor Ben Goldacre
MBE

Ben Goldacre is an award-winning writer, broadcaster, doctor, academic and campaigner who specialises in unpicking scientific claims made by scaremongering journalists, government reports, pharmaceutical corporations, PR companies and quacks. He trained in medicine at Oxford and UCL, in psychiatry at the Maudsley, and in epidemiology at LSHTM. He is currently Senior Clinical Research Fellow at the University of Oxford, Director of the Evidence-Based Medicine DataLab and Chair of the HealthTech Advisory Board. His books have sold over 600,000 copies worldwide and have been published in 31 languages. His academic and policy work is in epidemiology and evidence-based medicine, where he works on better uses of routinely collected electronic health data, variation in care, access to clinical trial data, efficient trial design, and retracted papers. He has written policy papers for the UK government, founded the AllTrials campaign, and in the 2018 Queen's Honours received an MBE "For Services to Evidence in Policy".

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