

## The impact of external loads carried by police officers on vertical jump performance

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*Recommended citation(APA):*  
Wiley, A., Joseph, A., Orr, R. M., Schram, B., Kornhauser, C., Holmes, R., & Dawes, J. (2018). *The impact of external loads carried by police officers on vertical jump performance*. 37. Abstract from 3rd International Conference on Physical Employments Standards, Portsmouth UK, United Kingdom.

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# PES|2018

**3rd International Conference on  
Physical Employment Standards**

University of Portsmouth,  
United Kingdom  
**17–19 July 2018**

## CONFERENCE BOOK OF ABSTRACTS



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**17 – 19 July 2018**

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**ISBN: 978-1-5272-2601-2**

FREE COMMUNICATION SESSION 1.1 - JOB TASK ANALYSIS

**A PRELIMINARY JOB TASK ANALYSIS OF THE PHYSICAL DEMANDS OF NON-GROUND CLOSE COMBAT ROLES IN THE BRITISH ARMY**

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INTRODUCTION

Despite the large variety of job roles within the British Army, most personnel operate under a 'Soldier First' ethos, whereby they are all trained to undertake Common Soldiering Tasks (CST) such as: casualty evacuations, loaded marching/dismounted patrols, manual handling, and offensive/defensive fire and movement. The Job Task Analysis (JTA) undertaken to develop Physical Employment Standards (PES) for Ground Close Combat (GCC) roles, measured the physical demands of CST. However, non-GCC roles may have additional or greater physically demanding tasks. This study aimed to (i) undertake preliminary JTA of all 191 non-GCC job roles in the British Army; (ii) identify the most physically demanding tasks for each job role [Role Specific Tasks (RST)] and; (iii) group job roles by their physical demands.

METHODS

The 191 identified non-GCC job roles were grouped into 36 role-groups. An internet-based survey was administered, with three sections: 1) Basic demographic information, 2) Selection and rating of up to five CST in terms of frequency and physical demands, 3) Selection, description, and rating of physically demanding RST in terms of importance, physical demands and frequency.

RESULTS

There were 1017 responders, with a mean of 28 individuals per role group (range 8-91). Responders were 84% men, 16% women; 24% Officers, 72% Other Ranks (ORs), with 4% failing to report a rank. Compared to the CST, 22% of responders rated their RST as more physical demanding and 78% rated it as less, with only three of the 36 roles-groups reporting a RST being more physically demanding. The identified RST were primarily single lift, repeated lift, or lift and carry tasks. Some roles were identified as having a limited physical demand and rarely completing CST, which should be considered when setting a minimum acceptable standard for future PES for British Army non-GCC roles.

CONCLUSIONS

British Army non-GCC roles generally report that CST are a requirement of their role and their RST predominantly involve manual handling-type activity. Based on these findings, 15 role groupings were identified for further detailed JTA of the British Army non-GCC roles.

# DEVELOPING A PHYSICAL EMPLOYMENT STANDARD ASSESSMENT FOR UNDERGROUND COAL MINES RESCUE BRIGADESMEN

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## INTRODUCTION

Coal Mines Rescue Brigadesmen are required to respond to emergency situations in underground mines that may be characterised by low light, variable terrain, constrained postures, non-respirable atmosphere, absence of motorised transport, team and individual manual handling tasks. Given the physical demands of the occupation, the aim was to develop a valid physiological aptitude test circuit based upon the criterion work tasks for Brigadesmen.

## METHODS

A project management group including trainers and assessors was appointed to oversee and approve each step. Firstly, task identification workshops and surveys were conducted with 45 representative Brigadesmen, Task parameters (load mass, distance, duration) and the physiological demands (oxygen consumption and heart rate) when performing those tasks was subsequently characterised with 24 Brigadesmen. A distillation process was used to identify criterion tasks with respect to postural, muscular and cardiovascular endurance, and muscular strength requirements. Seven unskilled individuals were used to develop tests of the criterion tasks. Those tests and a circuit (tests performed in series) were validated, by matching the physiological demand of tests with criterion task demands, with 58 Brigadesmen. Finally, familiarisation is known to influence performance, therefore reliability of the circuit was evaluated in 18 unskilled participants who performed the circuit three times.

## RESULTS

The criterion tasks identified were: move through a small hatch, sawing timber, sustained walking on undulating terrain and up a slope, casualty drag, stretcher carry, firefighting, build a roof support, shovelling, and lift-and-carry a wood pillar. The physiological demand of those tasks required moving masses of 8 to 93 kg and an oxygen consumption of 1.1 to 2.3 L.min<sup>-1</sup>, over durations of 15 s to ~30 min. The circuit included two postural tests (duck between two string-lines and push-pull) and a timed component: walk on a treadmill (4.2 km.h<sup>-1</sup>, 6% grade), dummy drag, unilateral and bilateral carries, hose drag, shelf-stacking, digging, unilateral carry, and a lift-and-hold. Following the reliability study, an 80 s performance buffer was implemented based on mean improvement plus the upper 95% confidence interval.

## CONCLUSIONS

A seven-step process was used to develop and validate a physical employment standard and physiological aptitude test circuit for underground Coal Mines Rescue Brigadesmen.

# DEVELOPMENT OF THE STANDARDISED PHYSICAL ABILITIES TEST FOR THE ADMISSION PROCESS AT THE ÉCOLE NATIONALE DE POLICE DU QUÉBEC

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## INTRODUCTION

Following the re-design of the basic training program in police patrolling (BTPPP), the Quebec police academy along with the Université du Québec à Trois-Rivières undertook the development of the standardised physical abilities test (SPAT-ENPQ) for the admission of police cadets. Owing to a past law dispute, admission at the academy has to be treated as the hiring process of a police organisation. Therefore, physical standard to be imposed must meet the Canadian bona fide occupational requirements (BFOR) to be legally admissible. It must be representative of the minimum physical requirements needed to undertake the critical and essential tasks in a safe and efficient manner. This paper relates the research project to the development of the SPAT-ENPQ.

## METHODS

The project was implemented in five phases: 1) pre-experimental process (familiarisation with training activities); 2) assessments of the tasks and physical demands; 3) development of the test; 4) measurement and determination of a cut-off score; 5) evaluation of the scientific accuracy and the discriminatory impact. For the second phase, 53 cadets were recruited (27 males, 26 females) and measurements were taken during 22 training activities. For the last two phases, 179 cadets were recruited (139 males, 40 females) to perform the SPAT-ENPQ in order to establish the quality of measurement and the cut-off score.

## RESULTS

The SPAT-ENPQ was developed using a hybrid approach that combine job-related tasks and tests to evaluate specific physical abilities. It is comprised of 11 stations, some of them are recurrent, that are performed in a continuous manner in a timed circuit. The applicants must put on a bulletproof vest and a weighted belt, which represents the weight of the equipment cadets must wear and totalling 6.8 kg. Based on the cumulative data from the 40 female cadets, the cut-off score was established at 322 seconds.

## CONCLUSIONS

The project led to the development and validation of a test that ensures that cadets have the minimally required physical abilities and capacities to safely and efficiently accomplish the tasks that are deemed critical to the police occupation and essential to a proper police training.

## ONGOING DEVELOPMENT OF A PHYSICAL COMPETENCY STANDARD FOR THE NATIONAL AMBULANCE RESILIENCE UNIT

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### INTRODUCTION

The National Ambulance Resilience Unit (NARU) works on behalf of each National Health Service (NHS) Ambulance Trust in England to strengthen national resilience and improve patient outcome in challenging pre-hospital scenarios. NHS Ambulance specialist operators are trained to deal with hazardous or difficult situations and mass casualty incidents. The aim of this study was to develop Physical Competency Standards (PCS) for NHS Ambulance specialist operators.

### METHODS

Phase 1: A two-day workshop with NARU Subject Matter Experts (SMEs) was completed to identify, a list of physically demanding criterion tasks undertaken by NHS Ambulance specialist operators. Phase 2: Staged reconstructions of the criterion tasks were performed by teams of trained NHS Ambulance specialist operators (29 men and 5 women) and the physiological responses and limitations to performance were documented. Phase 3: Individual performance during task reconstructions was compared to task simulations and gym-based fitness tests performed by NHS Ambulance specialist operators (23 men and 5 women) using rank-correlated Kendall's Tau.

### RESULTS

Phase 1: Eleven criterion tasks were identified and endorsed by the NARU Operations Group: Swift Water Rescue, Re-board Boat, Unload Vehicle and Set up Decontamination Unit, Carry out Clinical Decontamination, Movement in Gas Tight Suits, Marauding Terrorist with Fire Arms, Over Ground Rescue, Unload Incidence Response Unit Vehicle, Above Ground Rescue, Over Rubble Rescue, and Subterranean Rescue. Phase 2: All 11 criterion tasks were confirmed as viable and all five components of fitness (aerobic endurance, anaerobic endurance, muscular strength, muscular endurance and mobility) were required for successful task performance. Phase 3: The performance on the individual task simulation and / or key fitness parameters (as measured by the gym-based tests) demonstrated an acceptable correlation with completion time of the criterion task reconstruction.

### CONCLUSIONS

The present study has identified the critical physically demanding tasks performed by NHS Ambulance personnel to developed tests to measure their physical competency to complete these tasks. The data gathered during Phases 1-3 have quantified the physical challenges personnel face to successful complete their job tasks. This data can be used to inform potential evidence-based strategies (e.g. policy considerations, future equipment design, lifting aids and cooling strategies) to enhance the physical performance and safety of NHS Ambulance specialist operators.

## FREE COMMUNICATION SESSION 1.2 – PHYSICAL TRAINING FOR PES

### RELATIONSHIP BETWEEN THE OCCUPATIONAL PHYSICAL ASSESSMENT TEST, INJURY AND GRADUATION FROM ARMY INITIAL ENTRY TRAINING

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#### INTRODUCTION

The purpose of the U.S. Army Occupational Physical Assessment Test (OPAT) is to screen enlisted recruits into jobs they will be physically capable of performing. The OPAT consists of four events: the long jump, medicine ball put, deadlift and beep test. It is hypothesised that OPAT screening prior to Initial Entry Training (IET) may improve on-time graduation rates (GRs) and reduce musculoskeletal injuries (MSKIs). This paper will assess the association between OPAT scores, GRs, and MSKIs.

#### METHODS

947 men and 220 women recruits performed the OPAT prior to beginning IET. For one set of analyses, recruits were categorised into GR (on-time [GR+] or not on-time [GR-]) groups. Of these, 607 men and 132 women also completed a self-reported injury questionnaire at the end of IET and responded about any MSKIs that lasted seven or more days MSKI (injured [MSKI+] or not injured [MSKI-]). Two-way (group, sex) ANOVAs were used to determine differences in the OPAT scores of the GR and MSKI groups.

#### RESULTS

Of the total population, 16% of men and 13% of women were GR-. For each OPAT event, GR+'s achieved significantly higher scores than GR-'s ( $p \leq 0.01$ ), and this was true for men and women separately. Performance differences ranged from 2-14% in men and from 6-21% in women depending on event. In both sexes, the largest differences were in the beep test. Of 739 recruits who completed a questionnaire, 40% reported injuries [MSKI +]. There were no differences ( $p \geq 0.36$ ) in OPAT event scores based on injury status during IET.

#### CONCLUSIONS

Although higher OPAT performance was associated with increased GR+, these data do not demonstrate support for a relationship between higher OPAT performance and reduced MSKI. It is probable that some of the recruits who took the OPAT upon entering IET became injured but were recycled before the end of IET. These recruits would not have completed a MSKI survey and thus may have contributed to the observed absence of a relationship between OPAT performance and MSKI. Those who perform better on the OPAT were more likely to graduate with their peers, thus providing support for using the OPAT in the selection process.



## TIME-RELATED CHANGES IN STRENGTH, BODY COMPOSITION, AND PHYSICAL TRAINING VOLUME IN NAVAL SPECIAL WARFARE OPERATORS

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### INTRODUCTION

NSW Operators are highly trained individuals who engage in rigorous and dangerous military missions; therefore, it is vital to maintain a high level of physical performance throughout their careers. The purpose of the study was to evaluate changes in musculoskeletal and physiological performance characteristics and physical training habits.

### METHODS

44 NSW Operators completed a detailed physical activity questionnaire and laboratory testing assessing muscular strength and physiological characteristics at baseline and 2-3 years follow-up. Isokinetic strength was assessed using an isokinetic dynamometer (60°/s, 5 repetitions each), and average peak torque was normalised to body mass (%BM). Physiological assessments included air displacement plethysmography for body composition (body mass [BM], body fat [BF%], fat-free mass [FFM], fat mass [FM]), Wingate test for anaerobic power/capacity (Watts/kg), and a graded treadmill running protocol for aerobic capacity. Data were assessed for normality using Shapiro-Wilk tests. Paired t tests or Wilcoxon signed-rank tests were performed as appropriate. Statistical significance was set at alpha = 0.05, two-sided *a priori*.

### RESULTS

At follow-up, NSW Operators had significant increases in torso extension strength ( $374.5 \pm 117.7$ ;  $431.7 \pm 86.1\%BM$ ,  $p = 0.005$ ), torso extension/flexion ratio ( $1.60 \pm 0.41$ ;  $1.77 \pm 0.41$ ,  $p = 0.019$ ), cervical flexion/extension ratio ( $0.60 \pm 0.13$ ;  $0.69 \pm 0.17$ ,  $p = 0.038$ ), left knee flexion/extension ratio ( $0.49 \pm 0.06$ ;  $0.54 \pm 0.08$ ,  $p = 0.012$ ) and significantly lower cervical extension strength ( $32.8 \pm 5.5$ ;  $28.5 \pm 6.9\%BM$ ,  $p = 0.026$ ). No other significant changes in strength measures for the shoulder and knee were observed. Body mass ( $82.5 \pm 8.9$ ;  $84.3 \pm 10.5$  kg,  $p = 0.003$ ), BF% ( $15.9 \pm 5.4$ ;  $17.2 \pm 6.0\%$ ,  $p = 0.041$ ), FM ( $13.2 \pm 5.4$ ;  $14.9 \pm 6.5$  kg,  $p = 0.017$ ) significantly increased and there was no change in FFM or the remaining physiological variables. Physical training volume ( $86.9 \pm 47.9$ ;  $48.4 \pm 25.7$  MET Hours/Week [MET\_H/Wk],  $p < 0.001$ ) and endurance training ( $54.6 \pm 27.2$ ;  $26.6 \pm 17.5$  MET\_H/Wk,  $p = 0.004$ ) decreased, while strength training did not change ( $26.7 \pm 11.5$ ;  $27.8 \pm 19.8$  MET\_H/Wk,  $p = 0.782$ ).

### CONCLUSIONS

Although there was a significant decrease in total physical training volume, volume of strength training did not change; therefore, NSW Operators were able to maintain FFM and relative shoulder and knee strength. Significant favorable increases in agonist:antagonist strength ratios also occurred. The decrease in endurance training may in part explain the increases in BM, %BF and FM. Current strength training volume is sufficient to maintain/improve strength. Additional endurance training to reduce fat mass gain may allow Operators to more fully appreciate these gains in strength.

# A 12-WEEK STRENGTH BASED TRAINING PROGRAMME FOR RECRUITS IN PREPARATION FOR THE RAF REGIMENT PHYSICAL EMPLOYMENT STANDARD

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## INTRODUCTION

RAF Regiment (Regt) personnel must achieve the incumbent Physical Employment Standard (PES) by the end of Phase 2 training. Physical training during this period must support them to meet the PES. Therefore, the effectiveness of a 12-week physical training programme, delivered to male and female trainees, was examined during Phase 2 training.

## METHODS

53 RAF recruits (44 males [33 Regt and 11 Military Police] and 9 Military Police females) completed a 12-week training programme (70% strength, 25% loaded marching and 5% aerobic training), delivered during scheduled physical training. Measures of grip strength, Multi Stage Fitness Test (MSFT), and numbers of press-ups and sit-ups in a minute, were taken at weeks 0, 4, 8 and 12 of the training programme. Participants attempted the RAF Regt applicant PES at the start and end of training, and the RAF Regt incumbent PES at the end of training only.

## RESULTS

Males and females increased lean body mass (LBM) by 3.5% and 5.3% ( $p < 0.05$ ), respectively. Male grip strength increased from 43.0 kg to 46.6 kg ( $t_{(44)} = 4.8$ ;  $p < 0.001$ ) and 42.4 kg to 45.6 kg ( $Z_{(44)} = 4.0$ ;  $p < 0.001$ ) in the right and left hand respectively. Female grip strength increased from 31.3 kg to 34.8 kg ( $t_{(8)} = 2.8$ ;  $p = 0.024$ ) and 29.4 kg to 33.7 kg ( $Z_{(8)} = 2.2$ ;  $p = 0.028$ ) in the right and left hand respectively. Males increased their maximal single lift to 1.6 m from 45.3 kg to 49.6 kg ( $t_{(43)} = 4.0$ ;  $p < 0.001$ ). Females increased their number of press ups in a minute from 25 to 35 ( $Z_{(8)} = 2.0$ ;  $p = 0.04$ ). There was no change in MSFT. All participants passed the applicant PES and thirty-six males but no females, passed the incumbent PES. Participants that failed had lower grip strength, maximal single lift and MSFT scores. All females successfully completed at least one element of the incumbent PES.

## CONCLUSIONS

The 12-week strength-based training programme was successful in increasing the strength of male and female recruits but not their aerobic fitness. Increases in female strength were not sufficient to enable a pass in the incumbent PES. Future physical training programmes should focus on high intensity aerobic and strength training, tailored to specific individual requirements.

# EFFECTS OF DIFFERENT TYPES OF PHYSICAL TRAINING ON WARFIGHTERS SIMULATED COMBAT TASK PERFORMANCE

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## INTRODUCTION

Modern battlefield requires warfighters to have anaerobic capacity to fulfil the occupational requirements of high intensity movements with heavy load carriage. The purpose of the present study was to compare the effects of different types of physical training on the neuromuscular performance and simulated combat task course performance.

## METHODS

Seventy-three (age 20±1 years, height 180±6 cm, body mass 72.1±8.8 kg) male conscripts voluntarily participated in the study. They were divided to three training groups; soldier specific training group (TS), strength training group (ST) and control group (CON). Each group trained 0-3 times per week for 12 weeks with their instructor according to the specific training program. Skeletal muscle mass, fat mass, total body mass, counter movement jump (CMJ), anaerobic power, maximal isometric force of the upper and lower extremities and simulated combat task course performance were measured in the PRE, MID and POST measurement points.

## RESULTS

Maximal isometric force increased in leg press (TS 11.1% ( $p < 0.01$ ), ST 6.6% and CON 4.9%) and in bench press (TS 2.5%, ST 6.7% ( $p < 0.01$ ) and CON 1.9%). CMJ improved in the TS and ST groups (4.8%,  $p < 0.05$ ; 6.1%,  $p < 0.05$ ) but declined in CON (-3.4%). Simulated combat task performance improved in TS and ST more than in CON. Changes in the six-second cycle ergometer power test ( $r = -0.52$  to  $-0.77$ ,  $p < 0.05$ ) and CMJ ( $r = -0.62$  to  $-0.66$ ,  $p < 0.05$ ) were associated with the changes in combat task performance.

## CONCLUSIONS

The present study demonstrated that both the TS and ST training improved both neuromuscular and simulated combat task performance significantly. Further, the results show that anaerobic capacity is important in modern battlefield, and by utilising periodised TS or ST training, positive effects on warfighters' body composition and combat task specific performance can be achieved. It seems that the most effective way to train warfighters' strength could be by combining traditional strength training and anaerobic high intensity task specific training.

## FREE COMMUNICATION SESSION 2.1 – SPECIALIST ROLES

### PROFILING THE ABSOLUTE AND RELATIVE STRENGTH OF A SPECIAL OPERATIONS POLICE UNIT

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#### INTRODUCTION

Specialist police perform high-risks tasks and are required to have and maintain a high level of fitness. The aims of this study were to profile the strength, both absolute and relative, of a specialist police unit and to investigate whether this profile remained constant over an 18-month period.

#### METHODS

Retrospective data for 47 special operations police officers (mean initial weight = 88.84 ± 8.25 kg) were provided. Officers were tested five times over 18 months. Tests performed were: 1 repetition maximum (RM) bench press, squat, deadlift and pull up. All officers continued to participate in their typical physical conditioning programs which were provided by a full time Strength and Conditioning coach working in the unit. Sessions were typically conducted during work time. The coach and officers were blinded to the testing requirement (i.e. for research). Repeated-measures ANOVAs with Bonferroni post-hoc adjustments or Friedman tests with Wilcoxon signed-rank tests were used to compare strength values across all five time points (TPs). Alpha levels were set at 0.05.

#### RESULTS

All strength values increased significantly with no significant changes in bodyweight over the 18-month period. Over the five TPs, absolute squat increased the most (+9%: initial mean=125.79 ± 24.53 kg), followed by absolute bench press (+8%: initial mean = 109.67 ± 19.80 kg), absolute deadlift (+7%: initial mean = 151.64 ± 26.31 kg) and absolute pull up (+4%: initial mean = 121.43 ± 14.91 kg). A similar result was found in relative terms with the highest increase found with the squat (+8%: initial mean = 1.42 ± 0.25%), followed by the bench press (+7%: initial mean = 1.24 ± 0.20%), deadlift (+6%: initial mean = 1.71 ± 0.25%) then pull up (+4%: initial mean = 1.37 ± 0.15%). The period between TP3 and TP4 yielded the fewest significant increases compared with other TP differences with only absolute bench press (+1.7%), absolute squat (+1.1%) and relative bench press (+1.6%) changing significantly (p < 0.05).

#### CONCLUSIONS

Specialist police can maintain, even increase strength, while serving in specialist units if provided with a Strength and Conditioning coach and time to train. Strength profiles of specialist police officers can change and should be monitored constantly with no single time point used to categorise this group.

# PHYSICAL EMPLOYMENT STANDARDS FOR EXPLOSIVE ORDNANCE CLEARANCE PERSONNEL IN THE AUSTRIAN ARMED FORCES

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## INTRODUCTION

The admission criteria for entering Explosive Ordnance Clearance (EOC) Training at the Austrian Land Forces School include an "*extended mental and physical resilience*". The aim of this study was to develop physical employment standards (PES) for EOC candidates.

## METHODS

After evaluation of Standard Operation Procedures and typical movement patterns in the Explosive Protection Suit, an emergency scenario for EOC personnel was described by subject-matter experts. The scenario included a casualty rescue within a possibly mined area in the "single soldier method" (fireman's carry) and had to be accomplished in a pre-fatigued condition. Based on these requirements a Criterion Task Test (CTT) was developed to simulate operational conditions. A group of 30 male EOC candidates (age:  $21 \pm 3$  yrs, height:  $1.78 \pm 0.07$  m, weight:  $76.7 \pm 10.1$  kg) performed the CTT while time intervals and heart rate (HR) responses were measured in order to collect normative data. Additionally, anthropometric measures and physical fitness (PF) data were collected from the sample.

## RESULTS

During the CTT high levels of physiological exertion were reached, the mean average HR was  $166.4 \pm 5.4$  bpm or 87% HR<sub>max</sub>, respectively. 20% of the subjects failed to complete the CTT properly. The 24 subjects who succeeded were taller ( $1.80 \pm 0.06$  m vs.  $1.73 \pm 0.07$  m), heavier ( $77.9 \pm 9$  kg vs.  $71.9 \pm 13$  kg) and had a higher amount of Lean Body Mass ( $66.5 \pm 7$  kg vs.  $60.8 \pm 8$  kg) than the 6 subjects who didn't accomplish to finish the CTT. The successful candidates also reached higher levels of maximum strength and anaerobic capacity than the subjects who failed (bench press:  $88 \pm 11$  kg vs.  $78 \pm 12$  kg; bench pull:  $87 \pm 12$  kg vs.  $79 \pm 8$  kg; leg press:  $199 \pm 29$  kg vs.  $180 \pm 30$  kg). These findings were in line with the correlations between anthropometric measures, PF values and a ranking based on the CTT performance: significant coefficients ( $p \leq 0.05$ ) were found for LBM ( $r = 0.36$ ) and height ( $r = 0.38$ ), for measures of maximal strength ( $r = 0.40-0.54$ ) and the 1000 m runtime ( $r = 0.51$ ).

## CONCLUSIONS

The successful candidates had a robust physique, a higher amount of LBM and therefore greater muscular strength, which collectively led to a mechanical advantage while carrying heavy loads. In consideration of the mentioned findings and further data analysis PES for EOC candidates were developed and minimal performance requirements defined.

## DEVELOPMENT AND IMPLEMENTATION OF A SPECIAL OPERATIONS INSERTION / EXTRACTION COURSE PREREQUISITE PHYSICAL FITNESS EVALUATION

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### INTRODUCTION

The Canadian Special Operations Training Centre (CSOTC) provides the Canadian Special Operations Forces Command (CANSOFCOM) with common training and courseware, including the Special Operations Insertion / Extraction (SOIE) Course. Previously, all students enrolled on the SOIE Course were required to complete a prerequisite physical fitness evaluation (PPFE) within 365-days of the start of their course. However, due to limitations with the previous SOIE Course PPFE, students on course had a 7% rate of significant injury, anecdotally linked to physical fitness. Given the unacceptable injury rate, the Commander (Comd) CANSOFCOM directed that an evidence-based SOIE Course PPFE be researched, developed and implemented. The purpose of this paper is to describe the research, development and implementation of an evidence-based SOIE Course PPFE.

### METHODS

The most physically demanding components of the SOIE Course were identified by Subject Matter Experts (SMEs), including which physical fitness constructs were critical for their performance. These physically demanding components were subsequently quantified during 6 SOIE Courses by way of portable metabolic measurement systems and pre-post muscular strength and endurance measures. This data, combined with scientific literature was used to develop a PPFE and accompanying performance standards, linked to the unique physical demands of the SOIE Course.

### RESULTS

The following SOIE Course PPFE and accompanying standards were developed: i) Relative Hand Grip Strength,  $\geq 1.00$ ; ii) Standard Load Squat,  $\geq 11$  reps; iii) Pull-Ups,  $\geq 5$  reps; iv) Sit-Ups,  $\geq 40$  reps in 1-minute; and v) 20 m Shuttle Run,  $\geq$  Level 8.0. Additionally, it was established that students must achieve the PPFE within 30-days of the SOIE Course. Since implementation, the rate of significant injuries linked to physical fitness on the SOIE Course has dropped from 7% to 0%.

### CONCLUSIONS

The SOIE Course PPFE and standards were approved by the Comd CANSOFCOM on 11 April 2016. As indicated by the reduction in injury rates, and supported anecdotally by the SOIE Course Training Cadre, implementation of the SOIE Course PPFE has improved the physical preparedness of students and has helped to ensure that students possess the minimum physical capacities required to safely, effectively and reliably perform the physically demanding components of the SOIE Course.

## FREE COMMUNICATION SESSION 2.2 – ADVERSE IMPACT

### A DATABASE OF SEX BIAS FOR FREQUENTLY USED PREDICTOR TESTS

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#### INTRODUCTION

Many NATO military forces are removing barriers to women serving in combat occupations. A comparison of over 300 sources of physical performance data on generic predictive tests (GPT) by sex will inform physical employment standard (PES) development, addressing specific references to sex bias and adverse impact. These data may also assist in defining the effectiveness of physical training to reduce sex-related performance differences.

#### METHODS

Existing performance data were gathered from peer-reviewed and technical publications from 11 countries as part of a larger technical report led by the NATO Human Factors Medicine Group 269: Combat Integration: Implications for PES. As raw data were classified, weighted means were developed from 31 GPT measured maximally on military and civilian populations. Probability density curves were created to assess the percentage of overlap between male and female performance. Where female training data were available, the change in percentage overlap is presented to illustrate the potential reduction in sex-related performance differences.

#### RESULTS

The extremes of sex disparity were bench press (11 sources) and sit-ups (14 sources) with 9% and 93% overlap in performance, respectively. Pre- and post-training data were found for 13 GPT, with 12 pre and post-training sources contributing a combined sample of 2380 females. Pull-ups and squats showed the least improvement with training (3 sources; 2.3% and 4.0% changes in male-female overlap, respectively). VO<sub>2</sub>max and 38-cm upright pull showed the most improvement with training (10 sources; 35% and 25% changes in overlap, respectively) for females. The 31 GPTs are presented in an Excel Macro, ranking them from least to most percentage overlap. Such ranking can potentially highlight those GPT with reduced sex bias when predicting functional task performance.

#### CONCLUSIONS

These comparisons provide a valuable resource for PES researchers when developing a protocol while decreasing sex bias. The ability of the GPT to predict task performance is the most important factor; however, if GPT with more overlap in performance are chosen, this will facilitate the combination of male and female data for standards with reduced sex bias. Additionally, training effects on some GPT informs the researcher on which GPT have the most potential for improvement in female populations.

## IMPACT OF APPLYING DIFFERENT RESTING BLOOD PRESSURE CLEARANCE CUT-POINTS FOR PARTICIPATION IN VIGOROUS-TO-MAXIMAL INTENSITY EXERCISE

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### INTRODUCTION

The “best practice” procedure for physical activity (PA) participation screening in the fitness industry and physical employment standards testing for physically demanding public safety occupations involves the measurement of pre-exercise blood pressure (BP) measurement in combination with evidence-based screening tools such as the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and, if required, further screening through the ePARmed-X+ ([www.eparmedx.com](http://www.eparmedx.com)). Such screening practices are put into place to determine an individual’s risk category (e.g. low, intermediate, and high) before increasing PA levels and to ensure appropriate progressive PA intensity prescription. The purpose of this study was to examine the impact of applying six commonly-used and two proposed resting blood pressure (BP) cut-points to clear individuals for participation in vigorous-to-maximal intensity exercise.

### METHODS

Participants (n=1670) completed the PAR-Q+ and had their resting BP measured using the automated BpTRU device. Individuals with a BP >160/90 mmHg were further screened using the ePARmed-X+ for contraindications to PA participation with the end result that all 1670 were cleared. All participants underwent anthropometric assessments and completed vigorous-to-maximal intensity PA. There were no adverse events during or post PA participation.

### RESULTS

The percentages of participants cleared using each of the common BP cut-points were: 130/80 mmHg (85.3 %), 140/90 mmHg (93.4%), 144/90 mmHg (94.6%), 144/94 mmHg (96.3%), 150/100 mmHg (98.6%), 160/90 mmHg (95.6%) and using the proposed BP cut-points were 160/94 (97.8%) and 160/100 (99.5%). Individuals who would not have been cleared for vigorous-to-maximal intensity PA participation without further screening were significantly older, had a higher BMI, higher resting systolic and diastolic BP, were less aerobically fit and taking medication. Because of the nature of their risk factors, those individuals who would not have been cleared would undoubtedly benefit more from PA participation.

### CONCLUSIONS

We conclude that some BP cut-points currently used provide an unnecessary and burdensome barrier to PA participation. We recommend a resting BP cut-point of 160/94 mmHg be used to clear individuals who are categorised as low to moderate risk by evidence-base screening tools such as the PAR-Q+ and ePARmedX+, for participation in vigorous-to-maximal intensity PA.



## ACCURACY OF THE US ARMY OCCUPATIONAL PHYSICAL ASSESSMENT TEST CLASSIFICATIONS

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### INTRODUCTION

U.S. Army enlisted recruits must pass the Occupational Physical Assessment Test (OPAT) prior to beginning initial entry training (IET). The OPAT consists of the interval aerobic run, strength deadlift, seated power throw, and standing long jump. The OPAT is predictive of the ability to perform the critical physically demanding tasks (CPDTs) of combat arms Soldiers at the end of IET. These CPDTs include road marching, manual material handling, casualty rescues, ammunition reloading, and combat rushes. The purpose of this paper is to determine the relationships between group concordance and OPAT and CPDT passing scores.

### METHODS

A sample of 741 trainees (608 males, 133 females) completed the OPAT prior to IET and CPDTs for combat arms jobs at the end of their IET. Trainees were put in three groups based on whether they met the OPAT cut-scores at the combat arms level and whether they passed all of the job-specific CPDTs to the minimal acceptable performance standard: correct classification (CC; either passed or failed both OPAT and CPDTs), false positive (FP; passed OPAT, failed CPDTs), or false negative (FN; failed OPAT, passed CPDTs). Two-way (group, sex) ANOVAs with post-hoc Tukey adjustment were used to determine differences OPAT and CPDT scores.

### RESULTS

The OPAT correctly classified 76.6% of trainees, while it misclassified 6.7% as FP and 16.8% as FN. Compared to the CC group, FP scored lower ( $p < 0.01$ ) on three CPDTs: 28% lower on the casualty evacuation from a vehicle, 48% lower on the casualty drag, and 32% lower on the field artillery vehicle reload. And, compared to the CC group, FN scored 27% lower on the interval aerobic run and 7% lower on the standing long jump OPAT events ( $p < 0.01$ ).

### CONCLUSIONS

While there was a high classification concordance between the OPAT and CPDTs, the FP did not perform as well on the strength-dominant CPDTs and the FN group was slightly lower on the lower-body power and much lower on the aerobic OPAT events compared to the CC group. These data may provide insight on where cut-score adjustments might be made during period re-evaluations to improve the accuracy of the OPAT selection process.

# USE OF FITNESS TRAINING TO OVERCOME ADVERSE IMPACT IN PARAMEDIC PRE-EMPLOYMENT SCREENING

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## INTRODUCTION

The Ottawa Paramedic Physical Ability Test (OPPAT) is a physical employment standard for the paramedic sector. Individuals with lower fitness levels relative to their peer group demonstrate poorer performance, jeopardising their ability to pass the test. A fitness training program was developed and implemented to improve OPPAT performance. The purpose of this study was to test if a 4-week fitness training intervention can improve OPPAT completion time in those with poorer initial performance.

## METHODS

Twenty-one (n = 21) students enrolled in a paramedic program at Ontario colleges were recruited. During the first session, participants completed an initial OPPAT evaluation wherein completion time was taken as a measure of performance. Following the first session participants were dichotomised into control (n = 10) and intervention (n = 11) groups, where those with slower completion times were assigned to the intervention group. The intervention group completed a 4-week periodised training program with a focus on strength and power development, and movement competency. The program included three 1-hour sessions per week under the supervision of a Registered Kinesiologist. Following the intervention period both groups performed the OPPAT again. A two-way mixed ANOVA tested for differences in completion time between groups and across times.

## RESULTS

Mean OPPAT completion time decreased significantly by 89 seconds in the intervention group from an initial time of 905 (95) to 816 (93) seconds. OPPAT completion time did not significantly change in the control group. However, OPPAT completion times in the intervention group still remained significantly higher than the mean OPPAT completion time 734 (36) of the control group post-intervention.

## CONCLUSIONS

These results support that a fitness training program, targeting strength, power and movement competency, was effective at improving OPPAT completion time in those with lower initial performance. Improvements in completion time resulted in higher likelihood of meeting OPPAT success criteria. These findings support the need for inclusion of fitness training within the paramedic college training program to ensure candidates gain physical competency in addition to clinical competency. Future research could explore the utility of a smart phone application to coach exercise when supervision is not available.

# ADVERSE IMPACT STUDY: EVALUATION OF PHYSICAL EMPLOYMENT STANDARD (PES) BASED UPON PHYSICAL DEMANDS FOR SELF-EVACUATION ABOARD AN OFFSHORE OIL AND GAS INSTALLATION

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## INTRODUCTION

The adverse impact of a PES would indicate that testing may discriminate against an industry demographic. Therefore, trials are necessary to evaluate the appropriateness of a PES to isolate any necessary modifications/accommodations, especially regarding the potential development into a Bona Fide Occupation Requirement (BFOR). The purpose of the investigation was to determine whether or not the PES, developed from the study "*Measurement of the Physical Demands for Evacuation Aboard an Offshore Oil and Gas Installation*", was potentially discriminatory and/or suitable as a BFOR.

## METHODS

We examined, among 29 males and 16 females, the potential adverse impact of the PES developed from the minimum aerobic fitness (MAF) required to self-evacuate an offshore oil and gas installation from three different locations. The MAF required for Evacuation A & B was 9 METs ( $31.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1} = \text{High}$ ), with Evacuation C at 10 METs ( $35 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1} = \text{High}$ ). Aerobic fitness was measured by performing the modified Canadian Aerobic Fitness Test (mCAFT). The ability to meet the MAF was also compared against age, gender and obesity status.

## RESULTS

The age between men ( $38.21 \pm 8.8$  yrs) and women ( $36.88 \pm 13.6$  yrs) was not statistically different and nor was the level of METs attained. The MAF achieved decrease from 93.1% for Evacuations A & B down to 82.8% for C in men, where the MAF achieved for women was 75% for Evacuations A, B & C. In addition, although MAF was affected by adiposity, 79% of overweight and obese were able to meet the MAF requirements for Evacuations A & B. However, only 71% of overweight and 62% obese were able to meet the MAF for Evacuation C. Lastly, the calculation of the 4/5ths rule resulted in the percentages of females passing compared to males at 81% (9 METS) and 91% (10 METS) for the two aerobic standards.

## CONCLUSIONS

The findings indicate a slight gender difference in the MAF achieved, but the calculation of the 4/5ths rule suggests there is no adverse impact. As expected, adiposity did affect the ability to meet the MAF. However, this simply emphasises the need for overweight/obese employees to receive health/wellness accommodations in support of the PES implementation.

## EXAMINING POST-IMPLEMENTATION PASS RATES OF A NEWLY-DEVELOPED PHYSICAL EMPLOYMENT STANDARD (WFX-FIT) BETWEEN 2012 AND 2016

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### INTRODUCTION

In 2012, the Canadian Interagency Forest Fire Fighter Centre (CIFFC) implemented the Initial Attack (IA) Wildland Fire Fighter (WFF) physical employment standard (WFX-FIT) in all 13 fire jurisdictions. To be eligible for out-of-province exchange, IA WFF must meet the national exchange standard. There is growing literature detailing the development and implementation of physical employment standards, however there is limited analysis of post-implementation pass/fail rates. The objectives of this study were to: *i*) examine the pass/fail rates of IA WFF in each jurisdiction; *ii*) examine the pass/fail rates of IA WFF on the national exchange standard; *iii*) describe the successful candidates by age group and sex; and *iv*) to propose what other data beyond pass/fail rates by age and sex, needs to be documented to assess the effectiveness of implementing and administering a physical employment standard.

### METHODS

A retrospective descriptive analysis was conducted using aggregate data that were collected for IA WFF candidate selection purposes in Canada between 2012 and 2016. The main outcome variables are “meeting the WFX-FIT jurisdictional and/or national exchange standard”. Age-specific frequencies and proportions were calculated and compared among two age groups (< 40 years, ≥ 40 years) and by sex.

### RESULTS

Between 2012 and 2016, pass rates (%) on the jurisdictional performance standard were: All participants; 93.2, 96.0, 95.7, 94.5, and 95.6. Females; 82.9, 93.8, 91.1, 87.2, and 91.1. Males ≥ 40 years; 81.4, 89.6, 92.1, 82.0, and 89.8. Over the same 5 years, pass rates on the national exchange standard were: All participants; 79.1, 85.0, 86.7, 87.4, and 87.6. Females; 63.8, 79.4, 78.6, 77.3, and 80.2. Males ≥ 40 years; 46.6, 55.3, 59.6, 56.4, and 55.8.

### CONCLUSIONS

Since 2012, both the pass rates and pool of WFF available for exchange across Canada have increased especially for females. To better inform the effectiveness of implementing and administering a physical employment standard, in addition to the pass/fail rates by age and sex, organisations could document; pre-screening blood pressure, height, body mass, years of work experience, Aboriginal and other minority status, the WFX-FIT circuit completion time, where applicable the number of WFX-FIT circuit familiarisation attempts and absenteeism due to work-related injuries.

## FREE COMMUNICATION SESSION 3.1 – PREDICTORS VS. TASK SIMULATION

### THE PHYSICAL FITNESS CHARACTERISTICS THAT RELATE TO WORK SAMPLE TEST BATTERY PERFORMANCE IN DEPUTY SHERIFF RECRUITS

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#### INTRODUCTION

Law enforcement recruits are generally required to complete state-mandated physical tests prior to academy graduation. These tests, completed as part of a work sample test battery (WSTB), relate to job tasks (e.g., suspect pursuit, civilian rescue, obstacle clearance). Certain agencies will also have their recruits complete general fitness testing. The aim of the study was to determine relationships between fitness measured by an agency-specific test battery referred to as the PT500, and a state-specific WSTB in deputy sheriff recruits.

#### METHODS

Retrospective analysis on four academy classes (219 males, 34 females) from one agency was conducted. The PT500 and WSTB were completed in the last weeks of a 22-week academy training program. The PT500 comprised: number of push-ups, sit-ups, and mountain climbers in 120 s; maximal number of pull-ups; 220-yard and 1.5-mile run times. The WSTB comprised five tests completed for time: agility run (AR) around a 99-yard obstacle course; body drag (BD) with a 165-pound dummy; climb over a six-foot chain link fence (CL) and six-foot solid wall (SW); and 500-yard run (500R). Data were combined for the sexes. Pearson's correlations calculated relationships between the PT500 and WSTB ( $p \leq 0.05$ ). Stepwise regression determined whether the PT500 predicted WSTB performance.

#### RESULTS

Greater pull-up repetitions related to faster WSTB performance ( $r = -0.15$  to  $0.54$ ). Except for the BD, greater sit-up repetitions ( $r = -0.23$  to  $-0.36$ ) and faster 1.5-mile run times ( $r = 0.23$  to  $0.62$ ) related to faster WSTB performance. Greater push-up repetitions related to faster SW and 500R ( $r = -0.23$  to  $-0.25$ ). AR was predicted by pull-ups, push-ups, and 1.5-mile run time ( $r^2 = 0.27$ ). CL was predicted by pull-ups and push-ups ( $r^2 = 0.33$ ). 500R was predicted by pull-ups and 1.5 mile run time ( $r^2 = 0.45$ ). BD and SW were predicted by pull-ups ( $r^2 = 0.02$  to  $0.33$ ).

#### CONCLUSIONS

Recruits that completed more pull-ups performed better in the WSTB. The ability to do pull-ups may indicate the upper-body and absolute strength required in law enforcement. This should have application in not only the WSTB, but also job-specific tasks. Push-ups and the 1.5-mile run also correlated with and predicted WSTB tasks. To perform better in the WSTB and job-specific tasks, deputy sheriff recruits should develop upper-body strength and aerobic fitness.

# CARDIORESPIRATORY FITNESS AS A CUT-SCORE DETERMINANT FOR A MUSCULAR ENDURANCE ASSESSMENT

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## INTRODUCTION

Cardiorespiratory fitness is a key physiological requirement for muscular endurance tasks. Performance limitations are often due to impaired oxygen delivery rather than substrate availability for muscle contraction. To establish performance standards of muscular endurance tasks, maximal performance correlations is a well-established and valid method for determining an occupational fitness standard, even though tasks are usually performed sub-maximally. However, it is unknown whether setting sub-maximal (minimum) performance standards (cut score) using maximal performance scores reflects the cardiorespiratory fitness requirements at the cut-score. Therefore, the aim of this study was to compare the physiological demands of four different task-related predictive assessments and an associated criterion task (stretcher carriage) performed at maximal effort and at the previously determined minimum acceptable level of performance (cut-score).

## METHODS

Twenty-four Australia Army soldiers (18 males) completed five experimental trials. Either they carried a stretcher (four person carry; total mass: 90.5 kg), two jerry cans (22 kg each) or two kettle bells (22 kg each) a distance of 25 m then rested then repeated the course until volitional fatigue at either 4.5 km.hr<sup>-1</sup> or 5.0 km.hr<sup>-1</sup>. Oxygen consumption, heart rate and rate of perceived exertion were measured.

## RESULTS

There were no differences between any of the muscular endurance assessments for maximal oxygen consumption (L.min<sup>-1</sup>) at the point of volitional fatigue ( $p > 0.05$ ). Heart rate (beats.min<sup>-1</sup>) calculated at the cut-score was significantly higher for the jerry can carry (4.5 km.hr<sup>-1</sup>) than the stretcher carry ( $p < 0.05$ ).

## CONCLUSIONS

In conclusion, these results demonstrate that cardiorespiratory fitness is important in the setting of minimum acceptable level of performance for muscular endurance tasks. This is especially important if generic tests are used as predictors of occupational standards.

# PERFORMANCE ON FREDRIKSTAD FIREFIGHTER FITNESS TEST VERSUS APPROVED LABORATORY STRENGTH AND ENDURANCE TESTS FOR FIREFIGHTERS

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## INTRODUCTION

Firefighting is physically demanding and setting minimum physical standards is an important safety strategy. The aim of the study was to compare the approved laboratory tests in endurance and strength of The Norwegian Labour Inspection Authority (NLIA) with a simulated firefighter test (Fredrikstad firefighter fitness test; FFFT).

## METHODS

Twenty-two male and 6 female firefighters carried out the NLIA strength tests: push-ups, horizontal-chest-bar-pull-ups and squat-raise until exhaustion. A "strength index" was calculated from the strength tests. NLIA endurance test was up-hill treadmill walking with increasing intensity until exhaustion. NLIA requirement was 8 min. The FFFT tasks was hose carry, ladder carry and raise, hose drag, ladder climb, rope pull, hammer a truck tyre, victim rescue, ladder climb, hose drag, ladder lower and carry, ladder climb and spreader tool carry with walk in between the tasks as fast as possible. In all tests, firefighters carried clothing and self-containing breathing apparatus.

## RESULTS

There was no difference between males and females on all tests, except for push-ups. Push-ups  $14 \pm 7$  vs  $5 \pm 5$  repetitions ( $p < 0.05$ ), horizontal chest-bar-pull-ups  $16 \pm 5$  vs  $11 \pm 6$  repetitions, squat-raise  $32 \pm 9$  vs  $31 \pm 6$  repetitions, treadmill-test  $596 \pm 177$  vs  $598 \pm 160$  s and FFFT  $628 \pm 84$  vs  $784 \pm 174$  s. Performance of each strength test was poor related ( $r = -0.28$  to  $-0.54$ ) to the performance time of the FFFT, however strength index was fairly closely related ( $r = -0.62$ ,  $p < 0.01$ ). Performance on the NLIA treadmill-test was closely related to the FFFT (males:  $r = -0.78$ , females:  $r = -0.70$ ) and time on the FFFT could be predicted with an error of 70 s. FFFT time was 3 min shorter for the males compared to the females to fit the requirements of the 8 min of the NLIA treadmill-test.

## CONCLUSIONS

The FFFT may be used as an alternative to the NLIA treadmill-test for testing aerobic fitness, but not so for the strength tests. A gender independent time limit in under 12 min on the FFFT fit the requirements of the NLIA treadmill-test.

# MORPHOLOGICAL CHARACTERISTICS ASSOCIATED WITH SUCCESSFUL / NON-SUCCESSFUL PERFORMANCE ON OCCUPATIONALLY SPECIFIC, OPERATIONALLY RELEVANT PHYSICAL TASKS

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## INTRODUCTION

The United States Air Force (USAF) has expanded its research and development efforts of occupationally specific, operationally relevant (OSOR) physical fitness tests and standards. Knowledge of factors affecting success on OSOR physical tasks can provide valuable information for selection, training and operations. *Purpose:* we compared the morphological characteristics associated with success and non-success on operational physical tasks to inform targeted selection processes, training programs and operations for physically demanding career fields.

## METHODS

A bona fide occupational requirements physical demand analysis was conducted for seven USAF Battlefield Airmen career fields. Analysis identified operationally-required critical physical tasks, which provided the basis for developing physical task simulations (PTSs). Career field senior leaders and experienced operators reviewed PTS data to determine an operationally relevant minimum effective time (MET) for task success. Stature, body mass, body mass index (BMI), and fat-free mass, fat mass, and relative body fat from both bioelectric impedance (BIA) and skinfolds (SkF), and performance on 14 PTSs were recorded,  $n = 171$ , 62 female; age,  $28.5 \pm 5.6$  yrs. Successful performance required completing the PTS above the MET.

## RESULTS

Successful performers were significantly different than non-successful performers for all morphological characteristics measured (stature 176.7 cm - 167.8 cm, body mass 82.3 kg - 70.8 kg, BMI 26.3 kg/m<sup>2</sup> - 25.1 kg/m<sup>2</sup>, fat-free mass BIA 69.6 kg - 55.2 kg, fat-free mass SkF 72.6 kg - 58.5 kg, fat mass BIA 12.7 kg - 15.7 kg, fat mass SkF 9.7 kg - 12.3 kg, relative body fat BIA 15.2 % - 22.2 %, and relative body fat SkF 11.6% - 17.4%). Significance ( $p < 0.01$ ) was reached on a high majority of PTSs: stature 14 of 14 PTSs, body mass 13, BMI 10, fat-free mass BIA 14, fat-free mass SkF 14, fat mass BIA 11, fat mass SkF 11, relative body fat BIA 14, and relative body fat SkF 14.

## CONCLUSIONS

The study showed that significant differences in morphology exist between USAF Airmen who are successful and those who are not successful on operational physical tasks inherent to physically demanding military occupations such as USAF Battlefield Airmen.



## FREE COMMUNICATION SESSION 3.2 - LOAD CARRIAGE FOR PES

### THE IMPLICATIONS OF BODY MASS AND LOAD CARRIAGE FOR DEVELOPING AND IMPLEMENTING PHYSIOLOGICAL EMPLOYMENT STANDARDS

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#### INTRODUCTION

Many occupations require load carriage over variable gradients. Whilst we know that basal and ambulatory oxygen consumption data scale non-linearly with body mass, invalidating traditional normalisation practices ( $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), our understanding of the interaction of load carriage and gradients remains uncertain. The purpose of this investigation was to evaluate those relationships.

#### METHODS

Ambulatory oxygen consumption was measured in 72 men (23.0 y; 81.6 kg [range: 56.0-117.1 kg]), matched for height-adjusted adiposity and body mass. Participants completed two, 15-min treadmill walks ( $4.8 \text{ km}\cdot\text{h}^{-1}$ ) over three days: unloaded (battle dress and shoes) and loaded (25 kg vest). Different gradients were investigated each day (-5%, 0%, 5%), with both linear ( $y=ax+c$ ) and non-linear ( $y=ax^b$ ), least-squares regression models applied to the resulting datasets, and compared using analyses of covariance.

#### RESULTS

Non-linear scaling proved superior for all six datasets, yielding the following (untransformed) exponents for declined, level and inclined walking (respectively): unloaded:  $\text{mass}^{0.63 (\pm 0.10)}$ ,  $\text{mass}^{0.86 (\pm 0.06)}$ ,  $\text{mass}^{0.76 (\pm 0.04)}$ ; loaded:  $\text{mass}^{0.52 (\pm 0.09)}$ ,  $\text{mass}^{0.65 (\pm 0.07)}$ ,  $\text{mass}^{0.65 (\pm 0.06)}$ . Within each load state, changes in gradient did not significantly modify the scaling exponent ( $p > 0.05$ ). However, for comparisons across unloaded and loaded states, adding a torso load significantly reduced (flattened) the exponent ( $p < 0.05$ ).

#### CONCLUSIONS

In combination with our previous communications, we have demonstrated that the relationship between body mass and oxygen consumption scales non-linearly across the physiological range, including load carriage and graded walking. This means that the normalisation of oxygen consumption can, and should, be performed using either of two exponents: unloaded  $\text{mass}^{0.63-0.86}$ , loaded (steady-state walking)  $\text{mass}^{0.52-0.65}$ . These combined observations further challenge the use of linear normalisation, not just within exercising domains, but when such practices are used to establish physiological employment standards.

# THORACO-PULMONARY MECHANICAL PERTURBATIONS OF LOAD CARRIAGE INCREASE THE ELASTIC WORK OF BREATHING DURING SUBMAXIMAL EXERCISE.

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## INTRODUCTION

Thoracic loading decreases compliance of the total respiratory system in a mass dependent manner. These perturbations of the tissue elastic properties are likely to impact on the work of breathing. Therefore, we assessed that impact the combined effects of the restrictive and inertial forces accompanying thoracic loading, using a body armour and backpack ensemble, during standing rest and sub-maximal exercise.

## METHODS

Nine males (age: 27 [SD 5] y, height: 182 [SD 7] cm; mass: 79 [SD 8] kg) participated in three treatments: a control (clothing only) and two loads with a 25:75 mass distribution (35 and 54 kg) during two conditions: standing rest (n=9) and treadmill walking at 4.8 km.h<sup>-1</sup> (n=6) each lasting 15 minutes to obtain steady state. An oesophageal balloon (10 cm) was used to attain the static tissue compliance for the lung tissue, chest wall and total respiratory system. Elastic work of breathing for all three tissues were then calculated via integration between the respective static compliance curves and the zero pressure axis over the end-expiratory to end-inspiratory lung volumes during both standing rest and walking conditions. Values are reported as mean ( $\pm$  SEM).

## RESULTS

Increasing thoracic loading with the body armour and backpack ensemble (25:75 mass distribution) did not significantly modify the elastic work of breathing for the total respiratory system during standing rest (control:  $0.361 \pm 0.108$ , 35 kg:  $0.619 \pm 0.156$ , 54 kg:  $0.841 \pm 0.235$  J,  $p > 0.05$ ). However, when walking at 4.8 km.h<sup>-1</sup> the elastic work of breathing for the total respiratory system significantly increased in a mass dependant manner (control:  $0.299 \pm 0.185$ , 35 kg:  $0.838 \pm 0.277$ , 54 kg:  $1.105 \pm 0.365$  J,  $p < 0.05$ ).

## CONCLUSIONS

These observations demonstrate that the elastic work of breathing for the total respiratory system was increased by the body armour and backpack ensemble and this was most evident during submaximal exercise. A modified breathing pattern during standing rest likely protected against this physiological strain. The elevated elastic work of breathing during sub-maximal exercise, under conditions in which load carriage already elicits significant increases in ventilation, was unable to be avoided. This potentially predisposes the individual to respiratory-muscle fatigue during occupational load carriage tasks and thereafter decreased exercise tolerance.

## REPEATABILITY OF A FIRE AND MOVEMENT REPRESENTATIVE MILITARY TASK FOR THE UK ARMED FORCES GROUND CLOSE COMBAT PHYSICAL EMPLOYMENT STANDARDS

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### INTRODUCTION

Rank-stratified surveys and focus groups conducted with the UK Armed Forces' 10 Ground Close Combat (GCC) roles identified "fire and movement" as an essential and physically demanding military task. The aim of this study was to develop and determine the reliability (repeatability) of a field-based Representative Military Task (RMT) designed to simulate the physical demands of fire and movement.

### METHODS

Twenty-seven male GCC personnel (mean  $\pm$  SD: age  $24 \pm 4$  years, stature  $176.4 \pm 7.1$  cm, body mass  $82.6 \pm 11.5$  kg) completed the fire and movement simulation on two occasions separated by 24 hours. Whilst wearing assault order (~25 kg, comprising of webbing, weapon, helmet, body armour) participants completed five 30-m shuttles (total distance of 150 m) in 7.5 m bounds (total 20 bounds) in time to an audio track. Participants began the test in an unsupported prone position and on an audio command, rose, and had 5 seconds to sprint 7.5 m to the first marker and assume a prone firing position for 8 s. At the next audio signal they repeated this process, sprinting between the markers in a similar manner until they completed the 150 m course. On completion of the 20 bounds, participants' leopard crawled 15 m and then sprint 15 m. The total time taken to complete the crawl and sprint constituted the performance score. The difference in performance scores on the two separate days were analysed via paired t-tests, and test-retest reliability determined via Bland Altman Limits of Agreement (LoA), presented as Mean Bias (upper and lower LoA), and two-way mixed intraclass correlation coefficient [95 % confidence interval].

### RESULTS

There was no difference between the combined 30m crawl and sprint time on day 1 and day 2 (mean  $\pm$  standard deviation) ( $29.4 \pm 12.3$  vs  $28.4 \pm 7.0$  s, respectively,  $p = 0.46$ ). Intraclass correlation coefficient was 0.88 [0.76 to 0.95], indicating good reliability. There was mean bias of -0.56 seconds [95% LOA -8.4 to 7.3 s], with 21/27 (77%) and 24/27 (85%) of participants falling within 3 or 5 seconds of their initial test score.

### CONCLUSIONS

These data indicate that the fire and movement RMT possesses an acceptable level of reliability when assessed over two days.

## AEROBIC ENDURANCE IS MORE HIGHLY RELATED TO LOAD CARRIAGE PERFORMANCE THAN STRENGTH AND POWER

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### INTRODUCTION

Police officers are required to carry external loads as part of their occupation. One means of preparing officers to carry loads is through physical conditioning. The aim of this study was to investigate whether strength, power or aerobic endurance had the greatest association with load carriage performance.

### METHODS

Retrospective data from 42 male specialist tactical police officers (mean body weight =  $88.8 \pm 8.25$  kg) informed this study. Baseline data were provided for strength (1 Repetition Maximum [RM] Bench Press, Deadlift, Squat and Pull up), lower body power (Vertical jump, 10 m sprint) and aerobic ('beep' test) performance. In addition, officers completed three 5 km load carriage trials (3 to 4 months apart) with 25 kg packs as fast as possible. Pearson's correlations were used to investigate relationships between measures with an analysis of variance used to detect changes in load carriage performance. Alpha levels were set at 0.05 a priori.

### RESULTS

All variables of strength and power were significantly correlated with performance except for 1 RM Deadlift and the 10 m sprint for the last two load carriage trials. Aerobic fitness was the most highly and significantly correlated variable with all three load carriage trials ( $r = -0.712, -0.709$  and  $-0.711$  for the three trials respectively) apart from the actual correlations amongst the load carriage trials themselves (Trial 2  $r = 0.840$ , Trial 3  $r = 0.815$ ). Of the strength measures relative Pull ups were the most highly and significantly correlated variable ( $r = -0.607, -0.512, -0.541$  for the three trials respectively). Time to complete the load carriage trials improved across the three trials ( $p < 0.001$ ).

### CONCLUSIONS

These findings support the approach that optimal load carriage performance may be achieved by performing load carriage tasks in conjunction with aerobic fitness and full body strength / lower limb power training.

## FREE COMMUNICATION SESSION 3.3 – FUTURE CONSIDERATIONS FOR PES

### REVIEW OF METHODS TO IDENTIFY THE CRITICAL JOB-TASKS UNDERTAKEN BY THE EMERGENCY SERVICES

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#### INTRODUCTION

Emergency services (including Armed Forces and first responders) are reliant upon maintaining the capability with which to deliver their roles. Success of the capability is dependent upon the effective performance of a supported (e.g. equipment, facilities, training) and sufficiently resourced workforce to undertake specific roles. Employers are required by law to demonstrate every reasonable effort to protect their staff from undue risk of role-related injury. Implementing Physical Employment Standards (PES) contributes to such *duty of care*. PES has typically been based on the most common and critical tasks that are essential for safe and effective job performance (i.e. job-tasks). The first phase when developing legally-compliant PES concerns analysis of such job-tasks. However, different occupations have used varied criteria to define tasks that are truly *critical* to the role. This study sought to identify the method by which critical job-tasks have been determined when developing PES within the emergency services.

#### METHODS

Studies (reported in the open literature) which conducted analysis of job-tasks to develop PES within the emergency services were reviewed.

#### RESULTS

Twenty-two studies met the inclusion criteria. Methods to determine job-tasks varied but were typically criteria-based incorporating several techniques. Techniques included: Surveys (questionnaires, focus groups, interviews); facilitated expert judgement panels; review of policy and doctrine (including training manuals); historical analysis; case law; observation of training exercises; job appraisals; and consultation with Subject Matter Experts (SME) and stakeholder panels. Methods were mostly subjective and based upon reference to past or present job-task performance. Wargaming roles and scenarios planned for the future workforce (an established scenario-based model where the outcome and sequence of events affect, and are affected by, the decisions made by SME players) was not evident in any study.

#### CONCLUSIONS

Correctly determining critical job-tasks is essential for legally-defensible PES. A standardised method to define job-tasks remains to be established. The PES process should consider incorporating wargaming.

## CONSIDERING MOVEMENT COMPETENCY WITHIN PHYSICAL EMPLOYMENT STANDARDS

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### INTRODUCTION

Physical employment standards (PES) identify individuals who demonstrate requisite abilities to meet the demands of a workplace. The review paper emerging from the Second International Conference on Physical Employment Standards (Petersen et al. 2016) further highlights that PES may also help identify individuals that exhibit movement behaviours that may increase their risk of suffering a work-related injury. From this perspective, PES inherently include an opportunity to assess movement competency as a measure of one's safety or effectiveness of movement behaviour. However, approaches to objectively quantify, assess, classify, and score movement competency during the performance of dynamic tasks, like those embedded in PES, remain elusive. This paper describes an example of a data-driven movement assessment framework that may improve the assessment of movement competency, as a predictor of injury risk, within the PES paradigm.

### METHODS

The original proof-of-concept for the utility of the movement assessment framework was based on a sample of movement data obtained from 542 participants, performing a battery of movement activities as part of a general movement competency screen. Using the resultant motion data recorded from each participant, a pattern recognition technique was applied to objectively detect inter-participant differences in underlying movement features (e.g., greater hip flexion at movement initiation). A linear discriminant analysis was then applied to classify movers (in this example, as novice or elite) on the basis of those emergent movement features.

### RESULTS

Classification accuracy ranged from 70% to nearly 85% and was movement dependent. Using linear discriminant functions, motion data were reconstructed to visualise how unique movement features differed between novice and elite performers, providing a valuable opportunity to visualise and compare an individual's movement to an exemplar performance.

### CONCLUSIONS

Advances in motion capture, pattern recognition and machine learning create a powerful opportunity to embed data-driven, objective movement competency assessment into the PES paradigm. While challenges, such as the amount and type of motion data required and the identification of appropriate classifiers remain, this example application of a movement competency assessment approach demonstrates promise for application into the PES context.

# ASSOCIATIONS BETWEEN CHANGES IN MILITARY TASK SIMULATION, PHYSICAL FITNESS AND BODY COMPOSITION CHARACTERISTICS

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## INTRODUCTION

During military operations soldiers should be ready to immediately perform high-intensity tasks such as rushes, rapid changes of direction, jumping, climbing, crawling or lifting and carrying loads and casualty evacuation. However, characteristics of physical performance and body composition determining success in intensive tasks are not fully understood. Therefore, the purpose of the present study was to determine the associations of relative changes in physical fitness and body composition with changes in military simulation test (MST) performance.

## METHODS

Data was collected from 58 male soldiers ( $29.2 \pm 8.3$  yrs.,  $78.1 \pm 7.9$  kg,  $1.79 \pm 0.06$  m) at the beginning and at the end of a 6-month crisis management operation. Their body mass (BM) and composition were assessed by bioimpedance analysis, waist circumference (WC) and endurance performance via a 3000 m running test (3 km). Physical fitness tests consisted of push-ups, sit-ups, pull-ups and a standing long jump. Maximal isometric force of the lower and upper extremities was measured bilaterally in a sitting position by using electromechanical dynamometer. MST (length 243 m) consisted of typical occupationally relevant high-intensity tasks, and was performed wearing combat gear ( $19.5 \pm 1.0$  kg). Correlational and stepwise regression analyses were used for statistical evaluation of the associations between the relative changes in MST time and other measured variables.

## RESULTS

The mean MST time improved by  $11 \pm 7\%$  ( $p < 0.001$ ) during the 6-month military operation. The relative changes in MST correlated with 3 km ( $r = 0.46$ ,  $p < 0.01$ ) and fat% ( $r = 0.44$ ,  $p < 0.01$ ). Significant predictors of the change in MST included changes in 3 km, muscle mass and WC ( $R^2_{adj} = 0.36$ ,  $p < 0.05$ ).

## CONCLUSIONS

The present study demonstrated that the associations between the relative changes in MST and measured body composition and physical performance were modest. Improvement in endurance performance, an increase in muscle mass and a decrease in WC explained 36% of improvement in occupational physical performance, measured via MST. Thus, a major part of the change in MST performance was explained by other confounding factors such as motor learning and/or improved pacing strategy. However, MST can be considered as a useful tool for evaluating occupational physical performance.

## SELECTING CANADA'S NEXT ASTRONAUTS – DESIGNING PHYSICAL DEMANDS ASSESSMENTS

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### INTRODUCTION

Of all of the physically demanding occupations, one of the most challenging and unique is working in space. The constraints of the environment, impact of microgravity, limitations of the space suit and consequences of failure are extremely high. Canada contributes robotics and highly qualified astronauts to the International Space Station. In 2016-17, the Canadian Space Agency conducted an Astronaut Recruitment Campaign during which 3772 applicants seized this incredible opportunity to compete for two positions. Canadian Forces' Directorate of Fitness Human Performance Research & Development team (HPR&D) was directly involved in the task analysis, design and conduct of the first two of four assessment centres.

### METHODS

To fairly assess the physical demands of being an astronaut, HPR&D ran focus groups with incumbent astronauts (5 males – 1 female) to determine critical tasks that must be performed in flight and on the ground. Seventeen tasks were selected by the TRIAGE consensus process and developed into operational scenarios. Movement task analysis was subsequently conducted. Behavioural, cognitive as well as anthropometric requirements were also identified. The assessment centres started with 72 candidates and comprised multiple evaluation sessions for various critical attributes and competencies. For the physical component, field and functional tests, water phobias and proficiency, as well as detailed anthropometrics and mobility tests were conducted based on job requirements. In addition, specific sessions were designed to replicate the complexity of the job in combining cognitive, behavioural and physical demands together providing realistic job previews in the process.

### RESULTS

Physical sessions contributed to narrowing the potential candidates from 72 to 17 based on a scientific and legally defensible comprehensive scoring system designed from job requirements. Overall, 89 physical metrics were consolidated into 11 criteria used in the scoring. Results were analysed and recommendations were presented to the selection board for decision using a novel synthesis of cognitive and behavioural rankings matched with physical measures that facilitated a select-in process.

### CONCLUSIONS

Designing holistic assessment processes in collaboration with other professionals leads to successful selection of high-calibre candidates. Attention to detail and contextualising the assessments within the job also minimises the likelihood of a grievance.



## PERSONAL PHYSIOLOGICAL MONITORING IN THE MILITARY WORKPLACE

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### INTRODUCTION

In military jobs, there is an acknowledgement that individuals may be put in harm's way but there is also a public expectation that risks of harm have been minimised. Following the 1990-91 Persian Gulf War, a wide range of undiagnosed illnesses were attributed to a wide range of occupational exposures, with poor ability to resolve exposure-health outcome associations after the fact. A Physical Employment Standard (PES) typically provides a single or annual measurement of the minimum physical capability personnel require to perform their job roles. The information provided by a PES could be integrated with continuous through career measurements of their job tasks. These integrated data could be used to better inform organisations of the capability of their personnel to perform physically demanding job tasks and the outcome of exposure to potential hazards. The rise of personal wearable sensors has made possible the real time and continuous assessment of individual physiology which could be useful for workplace safety and health surveillance. This talk outlines issues related to physiological status monitoring (PSM) in the workplace.

### APPLICATIONS AND TECHNOLOGIES

(1) PSM can document triggering events such as head impact, psychological trauma, or neurotoxic chemical exposures and the subsequent evolution of changes in neurophysiological health, using measureable cardiovascular, voice, movement, activity patterns, and other signals; (2) tasks and equipment not matching human capacity/tolerances can result in chronic degenerative diseases through cumulative physical stresses that could be assessed with continuous measurement of kinetic and kinematic parameters (e.g., smart shoe); (3) acute occupational health and safety concerns such as thermal work strain can be better addressed with personalised monitoring than from generalised predictions that rely on estimates of external conditions and other assumptions.

### KEY ISSUES

To be useful, there must be a reliable physiological measurement or pattern of responses that signal a relevant exposure or health outcome. Occupational relevance can be demonstrated by concurrent assessment of the response with time and location data, and biometric signatures certify who was measured. Workers should be concerned about ownership and security of their data; distinguishing occupational health effects from personal medical data that can be derived from these measurements but not related to the job; determination of what may be reported to insurers or medical records; and efforts to assess individual work performance and productivity.

### CONCLUSIONS

PSM technologies make it possible to move from generalised workplace assessments to personalised health status assessments of the individual worker. It must benefit the health and safety of the individual, and personal health data must be firewalled from occupationally related data.

### THEMATIC POSTER SESSION 1A – JOB TASK ANALYSIS 1 SELF-RATED PHYSICAL WORK DEMANDS FOR GROUND COMBAT SOLDIERS

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#### INTRODUCTION

Military tasks are physically demanding, and the ability to achieve and maintain the physical capacity required to perform all military tasks are important. Previous studies in other countries have identified the most physically demanding work tasks to be carrying, lifting heavy loads, and digging. The aim of the present study was to identify the most physically demanding work tasks for Swedish ground combat soldiers and to study gender differences in perceived difficulty of the tasks.

#### METHODS

Based on procedural documentation, field manuals and job analyses, a questionnaire was developed that defined 30 work tasks for ground combat soldiers. To assess face and content validity, an expert focus group was used. The questionnaire was distributed to 231 ground combat soldiers, 165 of whom responded (71.4%), rating the perceived physical strain of the identified work tasks.

#### RESULTS

Of the 30 item work tasks included in the survey, five were selected as the most physically demanding. Transport of wounded was rated as the most demanding task both for aerobic endurance and strength. Other highly demanding tasks for aerobic capacity were low/high crawl, dismounted attack in close country, urban and rough terrain, and carrying heavy loads. For muscle strength demands there were a total of 11 different work task ranked for hand-, arm-, leg-, and core strength although many of them only occurred in one of the areas of interest. Carrying heavy loads were ranked in second place except for leg and core strength there it was in third place, instead high and low crawl was ranked very strenuous for leg and core strength. Care of wounded were ranked high for hand strength but not so hard for the rest of the areas.

#### CONCLUSIONS

Swedish ground combat soldiers rate many tasks as physically demanding. Almost all the identified tasks were physically challenging and contains elements of lifting and carrying, which demand personnel's muscular strength and muscular endurance capabilities for the soldiers. There were no significant differences in ranked physical requirements between male and female soldiers although they sometimes ranked the tasks in different order.

# RELATIONSHIP BETWEEN SELF-REPORTED COMBAT-RELEVANT TASK FREQUENCY, DIFFICULTY, AND IMPORTANCE

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## INTRODUCTION

Combat-readiness assessments evaluate a soldiers' ability to perform physically demanding tasks encountered in combat environments. Failure to meet these demands has implications for injury, mission-failure or fatality. However, limited information exists on combat-relevant tasks (CT) such that the relationship between task frequency, difficulty, and importance is unknown. These relationships are essential to understanding the physical demands of a combat environment and are crucial in the development of combat-readiness assessments. Our investigation aimed to identify the relationship between CT frequency, difficulty, and importance among US Army personnel.

## METHODS

A survey used with SWAT officers was modified by a retired Army Sergeant to contain CT and was validated by nine subject matter experts. The survey was distributed for five-weeks through Qualtrics, and participants were recruited via social media, veteran email lists and connections with military-affiliated individuals. After consenting, participants ( $n = 106$ , age =  $34.6 \pm 8.2$ , rank E4 and below = 40.6%) were asked to rate 15 CT for frequency (0 = never, 1 = sometimes, 2 = about half the time, 3 = most of the time, 4 = always), difficulty (0 = not applicable, 1 = easy, 2 = moderate, 3 = difficult, 4 = extremely difficult), and importance (0 = not important, 1 = moderately important, 2 = very important, 3 = mission-essential, 4 = vital to survive). A composite score was created for CT frequency, difficulty, and importance by averaging the ratings across all tasks within each category. A Pearson product-moment correlation determined the relationship between composite scores for CT frequency, difficulty and importance.

## RESULTS

Frequency and difficulty were moderately correlated ( $r = 0.427$ ,  $p < 0.001$ ). Difficulty and importance were weak-to-moderately correlated ( $r = 0.355$ ,  $p < 0.001$ ). Frequency and importance were weakly correlated ( $r = 0.308$ ,  $p < 0.01$ ).

## CONCLUSIONS

Frequently encountered CT were not strongly related to task importance. This is crucial when developing combat-readiness assessments as frequently occurring CT may not reflect tasks that are mission-essential or vital to survive; which may have implications for injury, mission-success, and survivability, and, thus retention of an effective military. Moreover, utilising an "overall score" may inappropriately identify CT that are inflated by high ratings of frequency or difficulty; thereby threatening the validity of the assessment and rendering the word "combat-ready" as a misnomer. Future investigations should validate our survey using focus groups, larger samples, and determine if these relationships exist among other branches.

## ROYAL NAVY SUBMARINERS RATE SUBJECTIVE PHYSICAL DEMAND OF COMMON TASKS HIGHER THAN SURFACE FLEET PERSONNEL

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### INTRODUCTION

Royal Navy (RN) submariners work in a constrained environment but perform similar tasks to surface fleet personnel. It is unknown if the physical demands of common occupational tasks are different between these fighting arms of the RN, which might have implications on subsequent RN Physical Employment Standard (PES) design. The subjective physical demand ratings of common role related tasks were compared between personnel supporting Surface Fleet (SF) and Submarine (SB) platforms.

### METHODS

A subjective physical demand questionnaire was completed by 545 (90% males; 9% females) RN personnel (Mean  $\pm$  SD; age  $29 \pm 7$  years; Service career  $8 \pm 7$  years) across eight different platforms (6 x SF; 2 x SB), that rated physical demand on a 1-6 scale (very light – maximum). Twelve tasks were identified as common to all platforms. Subjective ratings of physical demand were compared between platforms using Mann-Whitney U tests. Data are presented as median values.

### RESULTS

The physical demand ratings of fire fighting attack party without Extended Duration Breathing Apparatus (EDBA) (SF 2 vs. SB 3), EDBA fire attack party (SF 3 vs. SB 4), boundary cooling (SF 2 vs. SB 3), single person casualty carry (SF 4 vs. SB 5), two person casualty carry (SF 4 vs. SB 4), search and rescue (SF 3 vs. SB 4), casualty stretcher evacuation (SF 4 vs. SB 5), waste removal (SF 2 vs. SB 3), and information runner (SF 3 vs. SB 3) were significantly higher in SB than SF personnel (all  $p \leq 0.008$ ). Compartment re-entry, casualty hose lift and store ship were not different (all  $p \geq 0.179$ ).

### CONCLUSIONS

Nine out of twelve common RN tasks were rated more physically demanding by a sample of submariners, which could be a function of task-based differences and / or participant physical fitness differences. Separate Submariner and Surface Fleet job and physical demands analyses may be warranted in the subsequent PES development for RN seafarers.

## DIFFERENCES IN THE SUBJECTIVE PHYSICAL DEMAND RATINGS OF COMMON ROYAL NAVY SURFACE FLEET TASKS

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### INTRODUCTION

The Royal Navy (RN) has 18 different types of surface platform, which range from small survey vessels (15 m) up to aircraft carrier (280 m). The development of multiple RN Physical Employment Standards (PES), based on ship platform size would be a considerable undertaking that may not be warranted. This study explored subjective ratings of physical demand of common role related tasks across RN surface platforms of different sizes.

### METHODS

A subjective physical demand questionnaire was completed by 388 (88% male; 12% female) RN personnel (Mean  $\pm$  SD; age  $28 \pm 7$  years; Service career  $7 \pm 7$  years) from six platforms that spanned the different surface fleet types, where physical demand was rated on a 1-6 scale (very light – maximum). Ten tasks had an overall physical demand  $\geq 4$  (threshold criterion for initial down selection) and were identified as common to all surface fleet platforms. Platforms were categorised as small (Patrol and Mine Counter Measure Vessels), medium (Frigates and Destroyers) and large (Assault Ship and Ocean Survey). Subjective ratings were compared using Kruskal-Wallis H test and Dunn-Bonferroni post-hoc analysis. Data are presented as median values with interquartile range.

### RESULTS

Three out of the ten tasks were rated as significantly different based on platform size. Post-hoc analysis revealed that medium sized platforms rated fire fighting compartment re-entry higher (5: 4-5) than small (4: 4-5) ( $p = 0.011$ ) and large ships (4: 4-5) ( $p = 0.018$ ). First stage leak stopping had a higher physical demand rating on medium platforms (4: 3-4) compared with large (3: 3-4) ( $p = 0.011$ ), with no other significant differences (all,  $p \geq 0.266$ ). Physical demand rating of carrying a water egress pump increased with platform size (small 3: 2-4; medium 4: 4-5; large 5: 4-6, all  $p \leq 0.006$ ).

### CONCLUSIONS

The majority of common role related tasks were not rated differently for subjective physical demand as a function of platform size. These data support the notion that a RN PES could be developed from a single 'representative' platform. However, policy makers should be aware that there are some differences in subjective physical demand between platforms.

# APPLYING THE BOOKMARKING METHOD TO SHORT DURATION TESTS WITHIN THE ROYAL AUSTRALIAN NAVY

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## INTRODUCTION

Bookmarking is an accepted methodological approach to determine work task cut-scores in prolonged duration (>8 min) activities. However, bookmarking has not previously been applied to short-duration work tasks, which account for a significant proportion of criterion tasks performed within the Royal Australian Navy (RAN). Therefore, this investigation applied the bookmarking method to three short (<1 min) criterion tasks performed by RAN.

## METHODS

Casualty drag, casualty lift-and-carry and casualty fire-hose lift, were three short-duration criterion tasks within Navy. To develop the work samples (video speeds) for the bookmarking workshops, task experts were filmed completing each task twice (a slow and fast work rate); these were edited to create six work samples ~2-5 s apart. On two separate occasions, six experts at HMAS *Creswell* and 15 at HMAS *Cerberus* participated in the bookmarking workshops. Experts viewed the work samples from slowest to fastest (Round One) and discussed before a second viewing (Round Two). These same videos were then viewed in a random order (Round Three), where decision accuracy was calculated for each expert and averaged as a group, assessing their ability to correctly identify work rates as acceptable. An unpaired, non-parametric t-test was used to compare responses between experts from *Creswell* and *Cerberus*. Data presented as means and 95% confidence intervals.

## RESULTS

The average response corresponded with an acceptable drag speed of 33 (3.8) s after Round One and 37 (3.7) s after Round Two. The average response for the fire-hose lift was 13 (1.1) s for Rounds One and Two. Responses were not different between experts at *Creswell* and *Cerberus* for the drag or lift tasks. The average Round One response corresponded with an acceptable lift-and-carry of 17 (1.6) s and 16 (1.3) s for Round Two, however experts at *Creswell* deemed slower speeds to be acceptable (19 [2.8] versus 14 s [0.6],  $p < 0.05$ ). Decision accuracy in Round Three for the drag, carry and lift was 80% (9.3), 95% (3.7) and 83% (6.9), respectively.

## CONCLUSIONS

The bookmarking method is appropriate to determine the cut-score for short-duration tasks, where the mean plus 95% confidence interval was used to set the cut-score for the drag (41 s), lift (15 s) and carry (17 s).

## THEMATIC POSTER SESSION 1B – LOAD CARRIAGE CONSIDERATIONS FOR PES

### THORACO-PULMONARY MECHANICAL PERTURBATIONS DURING LOAD CARRIAGE: IMPACT OF THE MASS AND ITS DISTRIBUTION

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#### INTRODUCTION

Thoracic loading increases physiological strain and is accompanied by modified, and sometimes, impeded ventilation. However, the combined effects of the restrictive and inertial forces accompanying thoracic loading on the elastic properties of the entire respiratory system are unknown. Therefore, we assessed that impact by varying both the size and distribution of loads around the chest wall using a body armour and backpack ensemble.

#### METHODS

Eleven males (age: 27.27 [SD 4.78] y, height: 182.12 [SD 6.74] cm; mass: 79.55 [SD 8.42] kg) participated in four treatments: a control (clothing only), one load with a 50:50 mass distribution (anterior:posterior; 35 kg) and two loads with a 25:75 mass distribution (35 and 54 kg). An oesophageal balloon (10 cm) was positioned behind the right atrium and used to estimate intrapleural pressure. For each treatment, seated subjects performed static respiratory pressure-volume relaxation manoeuvres from residual volume to total lung capacity. Transpulmonary, transthoracic and transrespiratory static pressure-volume data were collected. Curve fitting permitted the *post hoc* attainment of tissue compliance for the lung tissue, chest wall and total respiratory system over end-expiratory to end-inspiratory lung volumes. Values are reported as mean ( $\pm$  SEM).

#### RESULTS

Increasing thoracic loading with 25:75 mass distribution reduced lung-tissue (control:  $4.91 \pm 0.68$ , 35 kg:  $3.82 \pm 0.26$ , 54 kg:  $3.04 \pm 0.31$  L.kPa<sup>-1</sup>,  $p < 0.05$ ), chest-wall (control:  $4.50 \pm 0.49$ , 35 kg:  $3.14 \pm 0.30$ , 54 kg:  $2.81 \pm 0.46$  L.kPa<sup>-1</sup>,  $p < 0.05$ ) and total respiratory compliance (control:  $2.64 \pm 0.26$ , 35 kg:  $1.65 \pm 0.10$ , 54 kg:  $1.40 \pm 0.09$  L.kPa<sup>-1</sup>,  $p < 0.05$ ). Varying the load distribution of 35 kg did not influence either lung-tissue or chest-wall compliance ( $p > 0.05$ ). Nonetheless, the 25:75 distribution decreased compliance of the total respiratory system compared to the 50:50 distribution (50:50 loading:  $1.92 \pm 0.10$ , 25:75 loading:  $1.65 \pm 0.10$  L.kPa<sup>-1</sup>,  $p < 0.05$ ).

#### CONCLUSIONS

The current observations demonstrate that the compliance of the total respiratory system was firstly reduced in a mass-dependant manner, and further modified by redistributing a greater proportion of a given mass onto the back. Such mechanical perturbations to the respiratory system are likely to elevate the elastic work of breathing under conditions in which thoracic load carriage already elicits significant increases in ventilation.

# THE IMPACT OF EXTERNAL LOADS CARRIED BY POLICE OFFICERS ON VERTICAL JUMP PERFORMANCE

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## INTRODUCTION

Police officers require a high level of lower limb power to complete occupational tasks. Deficits in lower limb power have been linked to an increased risk of injury in this population. With the addition of around 10 kg of external loads that police officers are required to carry, it is thought that the ability to perform explosive, power-based movements may be impacted. The purpose of this study was to examine the impact that external loads carried by police officers had on their vertical jump (VJ) height and peak anaerobic power output (PAPw).

## METHODS

Retrospective data of 47 (mean age =  $38.79 \pm 7.97$  years) police officers from a US Law Enforcement Agency (LEA) were used for analysis. Officers completed a VJ dressed either in gym clothing or in full duty attire and occupational loads ( $9.57 \pm 0.94$  kg, range 7.08 – 12.02 kg). VJ heights and body mass were used in the Sayers Peak Power Equation to calculate PAPw. Power-to-weight (P:W) ratios were then calculated by dividing PAPw by the officer's body mass. Paired samples t-tests were used to investigate differences in performance with alpha levels set at 0.05 a priori.

## RESULTS

While VJ height significantly ( $p < 0.001$ ) decreased with load (unloaded height =  $49.49 \pm 8.46$  cm; loaded height =  $43.62 \pm 7.68$  cm), PAPw increased significantly ( $p < 0.01$ ) (unloaded =  $4963.02 \pm 879.17$ ; loaded =  $5039.83 \pm 913.92$  watts). A Pearson's correlation showed a significant ( $p < 0.01$ ) low-moderate ( $r = 0.387$ ) relationship between absolute load ( $9.57 \pm .94$  kg) and change in PAPw, and a significant ( $p < 0.01$ ) strong ( $r = 0.794$ ) correlation between relative load and changes in P:W.

## CONCLUSIONS

This study supports previous research that suggests that occupational load carriage has a negative impact on VJ performance in police officers and may be detrimental to job performance. Targeted training programs aimed at increasing lower limb power may mitigate these negative effects.



## EXPLORATORY ANALYSIS OF GROUND REACTION FORCES DURING LOADED AND UNLOADED MARCHING AT DIFFERENT VELOCITIES.

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### INTRODUCTION

Load carriage factors into all occupational tasks in the military, altering performance capabilities and increasing musculoskeletal injury (MSI) risk. Physical employment standards aim to assess maximal mechanical and physiological qualities to predict high-risk MSI predisposition during load carriage. A dearth of research exists concerning propulsive variability as load and velocity increases. Impulse is an indicator of mechanical efficiency/energy dissipation. The purpose of this exploratory pilot study is to assess the kinetic differences in the lower extremities at different loads and velocities.

### METHODS

Four healthy adult subjects attended one session to perform walking tasks at various loads and marching velocities. Subjects performed two trials, five minutes each of an unloaded condition (UL) and a loaded condition (LD) with 30% of their body mass. Velocity linearly increased every minute and was standardised across all participants. The starting velocity was 1.5 m/s and subsequent velocities (increasing every minute) were: 1.77 m/s, 2.05 m/s, 2.33 m/s, and 2.61 m/s. Stage 1-3 was at marching velocities and stage 4 is a running velocity/forced march. Five strides of each limb were captured at each stage. Impulse was calculated and normalised by weight for each stride. Descriptive statistics were performed and GRF waveform plots were constructed for each stride in consecutive order of execution.

### RESULTS

Mean contact times for UL at each stage were: 1 = 0.59 s, stage 2 = 0.55 s, stage 3 = 0.5 s, stage 4 = 0.37 s. Mean impulse for UL at each stage were: stage 1 = 4.84 NS, stage 2 = 4.49 NS, stage 3 = 4.18 NS, stage 4 = 3.64 NS. Mean contact times for LD at each stage were: stage 1 = 0.62 s, stage 2 = 0.46 s, stage 3 = 0.49 s, stage 4 = 0.32 s. Mean impulse for LD at each stage were: stage 1 = 4.85 NS, stage 2 = 4.43 NS, stage 3 = 3.73 NS, stage 4 = 2.97 NS.

### CONCLUSIONS

Higher impulses were observed during the UL condition when normalized by weight. Considering the loaded condition had longer contact times, except during running that implies that the forces generated over that time period were less. Lower impulse magnitudes can indicate smaller propulsive forces and greater force absorption and energy dissipation. All of the participants were in a non-fatigued state and assessment indicated no potential risks to injury. However, this style of gait, while potentially protective against injury, is metabolically expensive and would be difficult to maintain for long periods of time. Load carriage assessed under fatigued conditions may offer stronger predictive value to determine a recruit's occupational readiness.

# PHYSIOLOGICAL DEMANDS ON PORTUGUESE CADETS: TIME SERIES ANALYSIS OF A LONG DURATION INFANTRY MARCH

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## INTRODUCTION

Military schools for Officers have existed in Portugal since 1641 and the long tradition on hard military endurance physical training dating back to the Portuguese Colonial War is presently still part of an infantry officer's training. Our aim was to evaluate the overall physiological demands of this emblematical military task, using a time series approach, in terms of Work and Physiological Occupational Performance, considering/bearing in mind the modern combat demands.

## METHODS

The case study/sample consisted of Infantry Course Officers (n = 4), who routinely run or march carrying approximately 15kg (G3 Assault Rifle, tactical vest, helmet). The participants completed a 33.3 km "night march" which is carried out in fighting load, on asphalt, along an old fortified defence line in an altitude profile that varies between 11-270 m ref. to sea level. Each subject accomplished the task on their own pace in order to achieve best effort performance. Intensity variables (MET) - Total Energy Expenditure (TEE), triaxial accelerations, skin-, near-body temperatures Heat-flux, and Heart Rates (HR) were measured along the trail/march. An integrated GPS registered the terrain profile (altimetry). Rate of Perceived Exertion (RPE) was obtained every 3 kilometers. We based our analysis on time series intervention modelling to evaluate effort/fatigue management (stochastic impacts) on terrain features (deterministic factors).

## RESULTS

To characterise this march, the integrated time analysis (RPE; HR; Speed; Altimetry) allowed us to identify *interventions* (critical events), both to subject and environment. All the movement speeds were submaximal (9.1 km/h  $\pm$  1.9). HR remained more or less stable (162  $\pm$  8). The concept of critical speed was useful for characterising this task and the best performers appeared to maintain heart rate while changing speed according to gradient. "Spots" of response production changes. RPE proved to be a good overall indicator of accumulated fatigue and with weak sensibility to course profile (Subject 1 r = -0.345 p = 0.272, Subject 2 r = -0.107 p = 0.740, subject 3 r = 0.464 p = 0.129, subject 4 r = 0.023 p = 0.944).

## CONCLUSIONS

By analysing the time series integrated data, forecasters can develop hypotheses to course policy changes or the continuation of tasks planned for the Cadets. This study showed the difference between the march's two different phases: The "even terrain" at the beginning allows the subject to adjust intensity individually while the latter "uphill" phase placed high physiological load on all subjects.

# INVESTIGATION OF THE USE OF MACHINE LEARNING ALGORITHMS TO IDENTIFY MILITARY LOAD CARRIAGE ACTIVITY

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## INTRODUCTION

The ability to monitor and quantify load carriage activity during military training could inform evidenced based interventions to reduce injury risk and improve training outcomes. This study assessed if a machine learning algorithm could be developed to identify load carriage activity from a wrist-mounted accelerometer.

## METHODS

Sixty-seven trained Ground Close Combat personnel walked at 2.5 and 4.8 km·h<sup>-1</sup> (simulating typical Patrol and TAB speeds) in repeated 20 min stages, carrying combinations of external load in a backpack and webbing, starting at 25 kg and then 30-70 kg in 10 kg increments. Participants wore an accelerometer on their left wrist (GENEActiv, Original, Activinsights, UK). Data were sampled at 100 Hz and recorded during minutes 11-20 of each stage. Raw acceleration data was analysed using previously adopted methods of activity classification, beginning with a Random Forest classifier, using features commonly used for activity classification. Upon determination that these features were inadequate for load carriage classification, two methods of automatic feature generation were tested: Convolutional Neural Networks and multi-layered Sparse Feature Encoding.

## RESULTS

Convolutional Neural Networks and multi-layered Sparse Feature Encoding methods achieved no significant improvement in classification compared to the Random Forest classifier. The classification was then reformulated into identifying: no load, moderate (25 kg) and heavy (30-40 kg). This reformulation led to a major class imbalance, which further impacted performance of the algorithm. Once the resulting class imbalance was dealt with performance of the classification showed no significant improvement and an accuracy of 50% possible for binary classifications (no load vs. load), dropping to 20% for the multiclass problem (no load, moderate, heavy). Analysis of these data showed differences between participants with identical loads far greater than intra-participant differences with different loads.

## CONCLUSIONS

It was not possible to detect load carriage activity with an acceptable level of accuracy using raw acceleration data measured from the wrist using these analysis approaches. This may be due to factors such as participants holding a static object (weapon) or, the small increments in load mass between stages. Further research should focus on determining if it is possible to detect load carriage starting from controlled laboratory-based movements and conditions.

## THEMATIC POSTER SESSION 1C – JOB TASK ANALYSIS 2

### PHYSICAL EMPLOYMENT STANDARD (PES) DEVELOPMENT STUDY: MEASUREMENT OF THE PHYSICAL DEMAND FOR SELF-EVACUATION ABOARD AN OFFSHORE OIL AND GAS INSTALLATION

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#### INTRODUCTION

The consequences of employing unfit individuals for the physically demanding work on an offshore oil platform can be costly, both in human and economic terms. Therefore, it is imperative that all workers are capable of meeting the demands of this environment. At a minimum, all employees should be capable of a self-evacuation to the Temporary Safe Refuge (TSR). This experimental research study was conducted to determine the physical demand of a self-rescue aboard an offshore oil and gas installation to be utilised in the development of a physical employment standard (PES).

#### METHODS

We measured the physical demand of the self-evacuation from three different positions on an offshore oil and gas installation with 15 participants who work within this environment. The demand was objectively measured through (i) real-time breath-by-breath sampling using a portable respirometry system (ii) and heart rate using a portable heart rate device and was subjectively measured with a Rate of Perceived Exertion (RPE) scale. Participants navigated the stairs, ladders and horizontal distances from the Evacuation A (Above Upper Deck), B (Pipedeck), and C (Derrick) to the TSR, respectively.

#### RESULTS

The physical demand of Evacuation A & B was 9 METs ( $31.5 \text{ mL.kg}^{-1}.\text{min}^{-1} = \text{High}$ ), with Evacuation C reaching 10 METs ( $35 \text{ mL.kg}^{-1}.\text{min}^{-1} = \text{High}$ ). The RPE scores ranged from 14 – 16 out of 20 on a Borg Scale corresponding to Evacuation A & B being "Somewhat hard" to "Hard" and Evacuation C being considered "Hard" to "Very Hard". Heart Rate was higher for Evacuation C than Evacuation A ( $p < 0.01$ ) and RPE was significantly greater for Evacuation C than Evacuation A ( $p < 0.03$ ) and B ( $p < 0.03$ ). The findings of this experimental research study were utilised to initiate the development of a PES via standardised testing.

#### CONCLUSIONS

These findings clearly indicate that the self-evacuation from an offshore platform was more vigorously demanding than initially suspected for those within this environment. Consequently, the minimal aerobic fitness is of importance to match the demand for the occupation. However, the implementation of the PES, through validity and reliability studies, is required to help provide guidelines to the offshore oil and gas industry.

## A CRITICAL TASK ANALYSIS FOR TECHNICIANS IN THE OFFSHORE WIND INDUSTRY

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### INTRODUCTION

In order to establish whether an organisation has a legally defensible Physical Employment Standard (PES), it is first important to determine those aspects of the job that are critical to its successful completion. The aim of this ethically approved study was to determine whether the current Offshore Wind industry standards adequately assess the ability of technicians to undertake critical tasks.

### METHODS

The task analysis was completed through: observations of technicians performing tasks; the research team undertaking tasks; reviewing operational manuals; and using focus groups with Subject Matter Experts (SMEs). The SMEs comprised of nine members of the Offshore Wind industry with varying experience and job roles. The physiological and biomechanical demands were determined by establishing the tasks in terms of climbing speed, duration, rest breaks, clothing ensembles, environmental conditions and methods of best practice. In addition, a review of existing PES for the Wind Industry was completed to determine whether these standards were appropriate.

### RESULTS

Five critical tasks were identified as the most physically demanding for technicians. These were: transfer from the vessel to the Transition Piece; ascent of the internal ladder; manoeuvre through hatches; torque and tensioning; and hauling a casualty up the tower. The critical tasks identified require a range of physical attributes including: mobility, upper and lower limb strength, strength-endurance, and aerobic capacity. With the exception of aerobic capacity, these physical components are not assessed by the current fitness standard, nor are the assessments standardised across companies. Additionally, the current standards for technicians are limited, and often not based on the demands of the job.

### CONCLUSIONS

The critical task analysis undertaken can be used to inform decisions regarding the physical fitness requirements, assessments and training of technicians, with a view of ensuring that they are physically capable of undertaking the critical tasks without undue risk of injury. Further investigation would be required to quantify the physical demands of the critical tasks. In order to do this the industry would need to agree minimum acceptable operating procedures for tasks in which loads and repetitions cannot be quantified.

## ROYAL NAVY TASK CRITICALITY RATINGS ARE BEST EXPLAINED BY THE POTENTIAL FOR INJURY OR DEATH

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### INTRODUCTION

Occupational tasks are frequently and interchangeably classified as critical or essential during Physical Employment Standard research. “Essential” task criteria have been described in relation to inadequate task completion that could result in injury or death, a compromised mission outcome, and / or Organisational asset damage. This study explored the relationship between a task criticality likert scale *versus* an essential task criteria frequency count.

### METHODS

Royal Navy (RN) personnel attached to eight operational platforms participated in a one-day focus group (n = 65). Participants were: 54 men, 11 women; age 32 ± 8 years, and comprised junior ratings (40%), senior ratings (31%), and officers (29%). Twelve common seafaring tasks constituting five duties (i.e. fire fighting, casualty handling, store ship, information runner, and waste removal) were rated on criticality from 1 to 6 (not important – critical). In the same tasks a frequency count of the essential task criteria was quantified for, injury or death, compromised mission, and Organisational asset damage. Spearman’s rank correlation coefficients explored the relationship between criticality ratings and the essential criteria count.

### RESULTS

Task criticality ratings for the five duties were (Mean ± SD): waste removal 3.6 ± 0.9; store ship 4.1 ± 1.1; information runner 4.6 ± 1.1; casualty handling 5.8 ± 0.5; and fire fighting 5.9 ± 0.2. The total frequency count when the three essential criteria were pooled (out of 195 counts) was: waste removal 23; store ship 51; information runner 82; casualty handling 80-83; and fire fighting 160-178. Task criticality had a strong positive correlation with the pooled essential criteria count (r = 0.76, p = 0.003). Assessment of the individual components of the essential criteria revealed injury or death had the strongest relationship with criticality (r = 0.81, p = 0.001), a compromised mission correlated moderately (r = 0.59, p = 0.029), but Organisational asset damage was not significantly correlated (r = 0.26, p = 0.222).

### CONCLUSIONS

Likert scale ratings of task criticality were correlated with essential task criteria classifications. These data suggested that the potential for injury or death when undertaking RN tasks may exert the greatest influence on subjective task criticality ratings.

# JOB DEMANDS ANALYSIS FOR THE ROYAL CANADIAN MARINE SEARCH AND RESCUE VOLUNTEERS OF BRITISH COLUMBIA

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## INTRODUCTION

The Royal Canadian Marine Search and Rescue (RCM-SAR) is a volunteer organisation with over 1000 members and 40 marine rescue stations that provides marine rescue service in British Columbia. The service area consists of more than 27,000 km of rugged coastline, over 6,000 islands and approximately 450,000 km<sup>2</sup> of internal and offshore waters. RCM-SAR members need to be able to carry out emergency response tasks in a timely manner for the safety of themselves, their crew and the public. RCM-SAR doesn't have a limit to how long their members can be out on the water meaning crews can be out for extended hours, often in extreme weather, with minimal sleep. The essential job tasks of RCM-SAR have not previously been identified thus the purpose of this research was to complete a job demand analysis (JDA).

## METHODS

A total of 14 site visits, over all four seasons, were completed to observe the training and rescue operations of the RCM-SAR. An online survey was sent to all RCM-SAR members to obtain demographic data, information about type and duration of call outs and opinion on essential job tasks. Measurements included of size and weight of tools and equipment, the type and repetition of loads moved, the frequency of tasks performed, time durations of each task and mission, and impact of environmental conditions (air temperature, sea conditions).

## RESULTS

One third of the RCM-SAR members (327 males and 50 females) completed the online survey. The average age of members is 48 years (range 19-74 years) with 8 years (<1-34 years) of experience. Mission lengths varied from <1 hour in length to over 14 hours with 70% of missions lasting 4 hours or more. Essential job tasks identified include: self-rescue, ability to balance and move around the boat in rough seas, safely lift, carry and transfer awkward loads between 2 and 40 kg, ability to clear the prop, throw a towline at least 60 feet and secure a tow or rescue line.

## CONCLUSIONS

There are several essential job tasks required of volunteers of the RCM-SAR organisation to allow them to safely and effectively carry out their duties. Like many emergency response occupations that have physical demand components to their jobs, the identified job tasks of RCM-SAR have a physical requirement and warrant the completion of a physical demands analysis.

## DEVELOPMENT AND IMPLEMENTATION OF FITNESS STANDARDS FOR NUCLEAR SECURITY OFFICERS AND RESPONSE FORCE IN CANADA

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### INTRODUCTION

Following the terrorist attacks on the U.S. on September 11 2001, the CNSC under section 47 of the *Nuclear Safety and Control Act* immediately issued an order to all nuclear facilities in Canada to implement appropriate security measures to prevent successful attacks from terrorist organisations. In parallel, the President of the CNSC ordered a complete review of the *Nuclear Security Regulations* taking into account the findings of recent CNSC studies and the expectations of International Atomic Energy Agency (IAEA). As part of IAEA's subsequent Amendment to the *Convention on the Physical Protection of Nuclear Material*, member states were advised on several fundamental principles, including defence-in depth for physical protection. In satisfying the personnel and organisational elements of defence-in depth for physical protection, the CNSC required nuclear power plant operators and nuclear facilities to establish onsite nuclear response forces to guard against intruders or invasions. To provide reasonable assurance with respect to the physical performance capabilities of security personnel, CNSC staff in conjunction with a third-party expert developed and implemented physical employment standards for nuclear security officers and response force. To ensure that the Canadian Nuclear Security Fitness Test (CNSFT) remains legally defensible, CNSC staff had the physical demands analysis updated for these security personnel across all high security nuclear facilities in Canada.

### METHODS

To understand what job-performance requirements had changed, job descriptions for each facility were reviewed and used to conduct targeted interviews with 157 security personnel. A focused physical demands analysis, including walk-downs of all equipment used in the course of normal duties, training, and tactical response activities, was conducted at each facility. Based on these assessments, the CNSFT was modified and new performance standards were established using a population of 95 security personnel.

### RESULTS

Three of the four component tests within the CNSFT were revised and performance-based time standards were established based on 67<sup>th</sup> percentile heart rate data.

### CONCLUSIONS

Incumbent testing with the revised CNSFT will be used to solidify the pass/ fail performance criteria in REGDOC 2.2.4, Volume III and REGDOC 2.12.1.



## THEMATIC POSTER SESSION 1D – PHYSICAL TRAINING CONSIDERATIONS FOR PES

### TIMING OF NUTRITIONAL INTAKE AROUND PHYSICAL ACTIVITY DURING MILITARY TRAINING

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#### INTRODUCTION

During military training, personnel undertake a variety of concurrent and repeated strenuous activities over repeated days and only eat when time permits. Nutritional intake during arduous training, specifically the quantity and timing, may affect performance adaptation and impact health and training outcomes. The aim of this study was to quantify nutritional intake and physical activity during military training.

#### METHODS

Ten male and 10 female Officer Cadets (OC) (mean  $\pm$  SD: age  $24 \pm 3$  years, stature  $1.73 \pm 0.07$  m, body mass  $78.9 \pm 9.0$  kg) undertaking the British Army Officer Commissioning Course at the Royal Military Academy Sandhurst completed food diaries for 10 days, alongside researcher-led dietary weighing. Energy, carbohydrate (CHO) and protein (PRO) intake were analysed using nutritional analysis software for each meal (breakfast, lunch, dinner) and intervening snack times (pre-breakfast, mid-morning, mid-afternoon, evening). Physical activity was measured using an accelerometer (Geneactiv, Activinsights, Cambridge, UK) and expressed as energy expenditure (EE, MJ) then averaged over the same intervals as the nutritional intake data. Repeated measures ANOVA was used to compare variables over time and independent samples t-tests to compare between sex.

#### RESULTS

Average hourly EE was similar for all time points except pre-breakfast ( $360 \pm 71$  KJ·hour<sup>-1</sup>,  $p < 0.001$ ) and evening ( $559 \pm 151$  KJ·hour<sup>-1</sup>,  $p < 0.05$ ), which was considerably lower than other meal times (lowest:  $560 \pm 113$  KJ·hour<sup>-1</sup>, highest:  $820 \pm 126$  KJ·hour<sup>-1</sup>). No sex differences in EE were found. Total energy intake was greater in meals compared to snacks (meals vs. snacks:  $2774 \pm 577$  MJ·meal<sup>-1</sup> vs.  $519 \pm 435$  KJ·meal<sup>-1</sup>,  $p < 0.001$ ), accompanied by higher PRO ( $27.2 \pm 6.2$  vs.  $3.1 \pm 2.3$  g·meal<sup>-1</sup>·d<sup>-1</sup>,  $p < 0.001$ ) and CHO ( $73.1 \pm 17.8$  vs.  $20.0 \pm 13.7$  g·meal<sup>-1</sup>·d<sup>-1</sup>,  $p < 0.001$ ) intake. Males had a greater intake of PRO ( $30.2 \pm 5.6$  vs.  $4.3 \pm 2.6$  g·meal<sup>-1</sup>·d<sup>-1</sup>) compared to females ( $24.1 \pm 5.1$  vs.  $2.7 \pm 2.0$  g·meal<sup>-1</sup>·d<sup>-1</sup>,  $p = 0.034$ ).

#### CONCLUSIONS

This study indicates that EE remained constant throughout the day during 10 days of training, but energy, PRO and CHO intake during snack periods were lower in comparison to meals and could be increased to support the demands of training.

## CHANGES IN SOMATOSENSORY AND SENSORIMOTOR FUNCTION FOLLOWING A BOUT OF BRITISH ARMY FOOT-DRILL

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### INTRODUCTION

Recent studies suggest the regimental movement patterns of British Army foot-drill may alter proprioceptive and neuromuscular performance capabilities, thus increasing lower-extremity musculoskeletal (MSK) injury risk. The development and implementation of Physical Employment Standards (PES) and recruit training practices necessitates that common military occupational tasks be examined in terms of their potential risk of injury to the recruit/soldier. Quantifying the physiological responses foot-drill has on female recruits in terms of risk of injury will better inform the structure and programming of PES and training practices within basic training. This study examined changes in lower-extremity proprioception and neuromuscular function in recruit aged-matched females pre-post a bout of British Army foot-drill training.

### METHODS

Fourteen healthy women underwent a bout of foot-drill training conducted by a British Army drill instructor. Changes in postural stability and ankle joint proprioception were recorded at baseline, pre and post foot-drill. The magnitude of JPS error between events for 30% and 60% of full inversion (IN), and 30% of full eversion (EV) quantified changes in ankle joint proprioception. The dynamic postural stability index (DPSI) and composite scores examined changes in dynamic balance for anterior-posterior (AP) and medio-lateral (ML) jump-landings. Non-linear dynamic analysis (sample entropy) quantified complexity and variability ( $m = 3$ ,  $r = 0.09$ ) of static postural stability.

### RESULTS

Significantly greater JPS error post foot-drill was observed for IN30% (%diff = 24.3,  $p = 0.024$ ) compared to pre-test values. Considerably greater JPS error was observed for IN60% (%diff = 15.6) and EV30% (%diff = 27.9) at post-test when compared to pre-test measures. Significantly greater DPSI, ML and AP stability index scores were observed for each jump condition post foot-drill training when compared to pre-test values ( $p < 0.05$ ), and greater regularity (lower sample entropy values) was observed for static postural stability for eyes open and eyes closed condition specific to the ML direction post foot-drill ( $p < 0.01$ ).

### CONCLUSIONS

Recruit aged-matched civilian females exhibited significantly greater JPS error, DPSI scores, and regularity (reduced complexity) post foot-drill training. These results indicate that the cyclic high impact loading forces and regimental movement patterns of foot-drill training are linked with changes and/or impairments in neuromuscular acuity and proprioceptive sensibility, suggesting that foot-drill may contribute to rates of lower-extremity MSK injury reported for female recruits; as JPS, along with measures of static and dynamic postural stability are recognised predictors of lower-extremity MSK overuse injury.

## GENDER DIFFERENCES IN CARDIOVASCULAR STRAIN DURING BRITISH ARMY OFFICER CADET TRAINING

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### INTRODUCTION

Male and female military personnel typically have to meet the same Physical Employment Standards (PES) and undertake common military training programmes. Understanding the physiological responses of male and female personnel to common military training programmes can help inform training practices. The aim of this study was to quantify the cardiovascular (CV) strain of male and female British Army Officer Cadets (OC) during a common basic military training programme.

### METHODS

Thirty-Five (21 male, 14 female) OCs (mean  $\pm$  SD: age  $24 \pm 2$  y, height  $1.76 \pm 0.10$  m, body mass  $79.9 \pm 11.1$  kg) volunteered to participate in one or more of three monitoring blocks during training (10-day block in camp, 6-day and 5-day blocks on field exercises). Participants wore heart rate (HR) monitors (Polar Team System, BodyCare, UK). The OCs CV strain was described as a mean percentage of Heart Rate Reserve (%HRR) and classified by time spent in the physical activity (PA) zones of sedentary (<20 %HRR), light (20-39 %HRR), moderate (40-59 %HRR) and vigorous ( $\geq 60$  %HRR). Overall %HRR and minutes spent in PA zones were compared using independent samples t-test with an alpha set at  $p < 0.05$ .

### RESULTS

Despite the common training programme female OCs experienced a greater overall CV strain ( $59 \pm 5\%$  HRR) than their male colleagues ( $53 \pm 5\%$  HRR;  $p < 0.05$ ). However, there were no statistically significant differences between men and women in the time spent in sedentary ( $281 \pm 151$  vs.  $219 \pm 137$  min $\cdot$ day<sup>-1</sup>), light ( $396 \pm 177$  vs.  $406 \pm 194$  min $\cdot$ day<sup>-1</sup>), moderate ( $98 \pm 60$  vs.  $150 \pm 99$  min $\cdot$ day<sup>-1</sup>) or vigorous ( $20 \pm 13$  vs.  $33 \pm 23$  min $\cdot$ day<sup>-1</sup>) PA zones, all  $p > 0.05$ .

### CONCLUSIONS

Overall the female OCs experienced a greater mean CV strain than male OCs. However, there were no differences between sexes for time spent in each PA zone. Further research is required to establish whether the higher cardiovascular strain results in more favourable changes in physical fitness during common basic military training programmes.

## ACCOMMODATION STUDY: SUPERVISED RESISTANCE TRAINING AND DIET VERSUS DIET ALONE TO DETERMINE THE OPTIMAL BODY WEIGHT MANAGEMENT PLAN

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### INTRODUCTION

For offshore installations, factors such as the availability of high caloric foods, limited opportunity for exercise, aging workforces and a rise in sedentary jobs may all contribute to workers becoming overweight or obese. Evidence related to the management of overweight and obesity is well established, however less is known about diet and exercise to manage weight for workers in remote locations. This research was conducted to assess the effectiveness of a 12-week supervised resistance training and diet program compared to a 12-week diet alone program.

### METHODS

This randomised control trial consisted of 51 inactive, overweight/obese (25-35 kg/m<sup>2</sup>), and but otherwise healthy males (35-55 yrs). These participants received either a twelve-week supervised strength training exercise + hypocaloric diet (n = 26) or hypocaloric diet alone (n = 25) intervention. Anthropometrics, body composition, biochemical markers and physical fitness were measured at baseline and post intervention.

### RESULTS

Both groups lost weight (Exercise + Diet = -4.6% and Diet Alone = -4.2%) (p < 0.001), however, there was no significant difference between the groups. Waist and hip circumference decreased (p < 0.001) with no significant difference between the groups. Total body fat mass (p < 0.001), body fat (p < 0.001) and trunk fat percentage (p < 0.001), and BMI (p < 0.001) all significantly decreased from baseline, with no difference between groups. Only the exercise group significantly increased lean body mass (1.2 kg) (p < 0.05). Visceral fat decreased in both groups with a 42% greater reduction with exercise than diet alone (p < 0.05). LDL cholesterol (-11%), total cholesterol (-10%), triglycerides (-27%), systolic (-6%) and diastolic blood pressure (-8%) and heart rate improved (-8%) with exercise, while diet alone only decreased heart rate (-9%). The Exercise + Diet group had a significantly greater increase in all fitness tests (p < 0.001).

### CONCLUSIONS

Exercise, in combination with diet, improves body composition, metabolic risk factors and physical fitness. Diet alone leads to similar weight loss as diet and exercise, without the cardiovascular health, muscle mass and physical fitness benefits. This study demonstrates that lifestyle intervention involving moderate caloric restriction with specific macronutrient ratios in combination with resistance exercise achieved increased physical fitness, decreased visceral fat, and improved cardiovascular health and can be readily applied to the offshore industry.

## YEARS OUT OF ACADEMY INFLUENCES GENERAL AND JOB-SPECIFIC FITNESS IN DEPUTY SHERIFF INCUMBENTS

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### INTRODUCTION

Law enforcement recruits are often required to complete general fitness assessments (e.g. muscular strength, aerobic capacity) and state-mandated physical ability tests relating to job tasks prior to graduating academy. However, few law enforcement agencies mandate that incumbents maintain their general fitness or physical abilities during employment. The aim of this study was to determine the influence of years out of academy on fitness measured by agency- and state-specific testing batteries in deputy sheriff incumbents.

### METHODS

Retrospective analysis on one patrol school class (48 males, 12 females; average tenure: 5.44 years; average age: 32.97 years) from one agency was conducted. Patrol school was a three-week skills refresher program completed by incumbents who had been working in custody. The fitness assessment comprised of: resting heart rate, blood pressure, waist-to-hip ratio, grip strength for each hand, number of push-ups and sit-ups in 60 s, and YMCA step test recovery heart rate. The job-specific work sample test battery (WSTB) was comprised of five tests completed for time: an obstacle run (OR) around a 99-yard obstacle course; a body drag (BD) with a 165-pound dummy; a climb over a six-foot chain link fence (CL) and six-foot solid wall (SW); and a 500-yard run (500R). Incumbents were grouped based on time elapsed from academy graduation (Group 1:  $\leq 24$  months [ $n = 18$ ]; Group 2: 24-48 months [ $n = 22$ ]; Group 3:  $\geq 48$  months [ $n = 20$ ]). A one-way ANOVA with Bonferroni post hoc compared data between the groups ( $p \leq 0.05$ ).

### RESULTS

Group 3 were significantly older than Groups 1 and 2 ( $p = 0.010-0.027$ ), and completed significantly less sit-ups compared to Group 2 ( $p = 0.006$ ). Regarding the WSTB, Group 3 was significantly slower in the OR ( $p = 0.033-0.035$ ), BD ( $p = 0.002-0.022$ ), and CL ( $p = 0.007-0.011$ ) compared to Groups 1 and 2. No significant between-group differences were observed in the SW and 500R.

### CONCLUSIONS

Younger incumbents closer to academy graduation performed better on select WSTB tasks, including the OR, BD, and CL. In combination with sit-ups, which assesses abdominal strength endurance, these occupationally-relevant ability tests require agility, strength, power and anaerobic fitness. These data suggest deputy sheriff incumbents should focus on developing or maintaining these qualities during their employment.

## THEMATIC POSTER SESSION 2A – ENVIRONMENTAL CONSIDERATIONS FOR PES

### HYDRATION STATUS OF CANDIDATES UNDERGOING CONDUCT AFTER CAPTURE TRAINING

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#### INTRODUCTION

Conduct After Capture (CAC) training is designed to introduce candidates to the physical and psychological aspects of captivity. To achieve this effect, water and caloric intake are restricted, which is reflective of real captivity. A previous study by Defence Research & Development Canada found that candidates lost a mean of 3.0 kg body mass (BM) during CAC, assumed to be a result of dehydration. Dehydration results in a state of hypohydration, which can adversely influence physical and cognitive performance, which is critical when candidates are expected to immediately undergo additional rigorous and specialised training upon completion of CAC. The purpose of this paper is to describe the assessment of the hydration status of candidates undertaking CAC training.

#### METHODS

Prior to the commencement of CAC, candidates who volunteered to participate provided urine samples to determine their urine specific gravity (USG), as well as had their total body water (TBW) and BM determined via bio-electrical impedance (InBody<sup>®</sup> 520). These measures were repeated upon completion of CAC to identify changes. Of the 47 participants who completed measures prior to CAC, only 41 completed the training, resulting in an effective sample size of 41. Paired samples t-tests ( $p \leq 0.05$ ) were used to compare pre-and-post measures for each dependent variable.

#### RESULTS

When comparing pre-and-post values, USG significantly ( $p < 0.001$ ) increased from  $1.018 \pm 0.006$  g·mL<sup>-1</sup> to  $1.021 \pm 0.005$  g·mL<sup>-1</sup>, TBW significantly ( $p < 0.001$ ) reduced from  $51.3 \pm 6.7$  kg to  $50.6 \pm 6.3$  kg and BM significantly ( $p < 0.001$ ) reduced from  $84.2 \pm 10.2$  kg to  $82.4 \pm 9.6$  kg. According to guidelines established by the American College of Sports Medicine, following CAC only 1 (2%) candidate was euhydrated (USG  $< 1.020$  g·mL<sup>-1</sup>), while 20 (49%) were dehydrated (USG 1.020-1.029 g·mL<sup>-1</sup>) and 20 (49%) were seriously dehydrated (USG  $\geq 1.030$  g·mL<sup>-1</sup>). Prior to training, 25 (53%) candidates were euhydrated, 21 (45%) were hypohydrated and 1 (2%) was seriously hypohydrated.

#### CONCLUSIONS

Due to the restriction of water and caloric intake during CAC, 98% of candidates completing CAC were dehydrated or significantly dehydrated and lost a significant amount of TBW and BM. Combined with the fact that only 53% of candidates arrive at CAC in a state of euhydration, it is recommended that pre-and-post hydration guidelines be developed for candidates undertaking CAC.

## PREVENTION OF UNCOMPENSABLE HEAT STRESS IN PROTECTIVE CLOTHING BY PROMOTING EVAPORATIVE HEAT LOSS DURING REST PERIODS

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### INTRODUCTION

Emergency responders, military personnel, employees in industry, trade or health service often require complex protective clothing. The thermal insulation of these garments limits heat dissipation and increases the risk of uncompensable heat stress resulting in limited tolerance time. Effective heat dissipation in breaks is only feasible by complicated undressing. Reducing heat stress without requirement to undress would allow for a much easier crossover between rest and work periods. From a physiological point of view heat mitigation may be improved best by promoting sweat evaporation. It is hypothesised that overall working time can be extended by using this mechanism.

### METHODS

Twelve male volunteers in protective overalls performed a balanced repeated measures within-subjects design test in a climatic chamber (25°C, 50% RH, 0.2 m/s wind speed). They were exposed to a work-rest schedule (work: 20 min, treadmill, 3 km/h, 5% incline - rest: 20 min; overall max. 205 min, incl. 5 min rest right at the start) with (cooling rest condition) or without (non-cooling condition) insufflating dry air (600 L.min<sup>-1</sup>, <3% RH, 30°C) into the microclimate of an additional air-diffusing garment layer during rest periods.

### RESULTS

Under cooling rest condition all participants completed the full test. Under non-cooling condition eight volunteers had to terminate the test prematurely: five due to core temperatures of 39.0°C (125 min: n = 2, 165 min: n = 3), two because of fatigue (115 min, 136. min) and one due to cardiac exhaustion (165 min). Only four of the participants tolerated the heat under this condition for the full 205 min. At the end of the tests their heart rates (Mean ± SD) were significantly lower under the cooling rest condition (88.5 ± 7.3 b.min<sup>-1</sup>) compared to the non-cooling condition (140.2 ± 7.1 b.min<sup>-1</sup>, p ≤ 0.01).

### CONCLUSIONS

Promoting evaporative heat loss during rest periods facilitates effective heat dissipation in protective clothing. Reducing risks of uncompensable heat stress it leads to essential extensions of tolerance time. Work can be resumed after a cooled rest period while decreasing the overall demand for personnel resources by exchanging between working and resting personnel several times.

## THE EFFECTS OF SIMULATED ALTITUDE ON COGNITIVE FUNCTION

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### INTRODUCTION

Whilst it is generally accepted that cognition is impaired under hypoxia, the large disparity in methodologies employed in the existing literature has made drawing definitive conclusions problematic. Moreover, it is still unclear i) at what level of hypoxia cognitive impairment begins, ii) the cognitive domain(s) that is/are affected, and iii) the mechanism(s) responsible for these deteriorations. Therefore, the aim of this study was to assess a variety of central executive and non-executive tasks and the concurrent changes in physiology over a range of simulated altitudes. It was hypothesised that there would be a linear relationship between fraction of inspired oxygen (FiO<sub>2</sub>) and cognitive performance, with non-executive tasks displaying greater resilience to hypoxia than executive tasks.

### METHODS

A within participant, balanced, crossover design was employed. Twelve healthy male participants (mean [SD] 22[4] yrs, 75[9] kg, FEV<sub>1</sub>/FVC ratio 85[5] %) completed a 4-task cognitive testing battery designed to examine the cognitive domains of inhibition, selective attention (Eriksen Flanker), working memory (N-back) and simple and choice reaction time (Deary-Liewald). The battery was completed before and after 60 minutes of exposure to each of the following FiO<sub>2</sub> values: 0.21 (sea level), 0.17 (~1600 m), 0.15 (~2800 m), and 0.12 (~4300 m). Peripheral oxygen saturation (SpO<sub>2</sub>), cerebral oxygenation (measured via near-infrared spectroscopy), minute ventilation, mood disturbance and acute mountain sickness were also recorded.

### RESULTS

As designed, SpO<sub>2</sub> decreased as altitude increased (FiO<sub>2</sub> 0.21: 96[0] %, FiO<sub>2</sub> 0.17: 94[2] %, FiO<sub>2</sub> 0.15: 89[2] %, FiO<sub>2</sub> 0.12: 81[4] %,  $p < 0.05$ ). Despite a significant reduction from baseline in cerebral oxygenation (-5.72[2.9] %,  $p < 0.001$ ) and an increase in mood disturbance ( $p = 0.049$ ) following exposure to FiO<sub>2</sub> 0.12, cognitive performance was maintained for both central executive and non-executive tasks across all conditions (all  $p > 0.05$ ).

### CONCLUSIONS

These results suggest that a simulated altitude of up to ~4300 m and the resultant physiological changes do not provide a sufficient stimulus to impair cognitive function at rest. These findings may have implications for those visiting and working at altitude.



## THE THERMAL CONSEQUENCES OF FLOOD RESCUE: REQUIREMENT FOR A PES?

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### INTRODUCTION

There are significant deficiencies in the knowledge of human factors surrounding flood rescue (FR). Little advice exists on the fitness required, or the recommended limits of exposure of FR technicians in hot or cold conditions.

### METHODS

10 participants undertook two conditions: “Cold” - required participants to stand immersed to the knee in moving (4.8 km.h<sup>-1</sup>) water (7.7 °C), with simulated rain for 60 min. Air temperature and wind speed were set to 4 °C, and 16 km.h<sup>-1</sup> respectively. “Hot” required participants to perform repeated bouts of 7 min walking at 2.16 km.h<sup>-1</sup> whilst immersed to the knee in water (15.6 °C), flowing at 3.2 km.h<sup>-1</sup> water, pulling (into flow) and controlling (with flow) the release of 10 kg. Air temperature, wind speed and radiant heat load were 22 °C, 0 km.h<sup>-1</sup> and 500 W.m<sup>-2</sup> respectively. Participants repeated this 6 times with 3 minutes rest between activities. Participants wore flood rescue personal protective clothing and a lifejacket totalling 9.25 kg. Deep body (gut and rectal) temperature and skin temperatures (biceps, chest, thigh, shin, finger, Great Toe), metabolic rate, thermal comfort, rating of perceived exertion, skin wettedness, grip strength, manual dexterity, jump height and resuscitation were measured pre and post exposures.

### RESULTS

In the cold exposures cooling resulted in great toe and finger temperatures of 9.98 (0.84) °C and 10.38 (8.21 to 12.10) °C respectively. Oxygen consumption rose from 7.46 (1.88) to 10.04 (3.13) mL.kg<sup>-1</sup>.min<sup>-1</sup>, jump height fell by 20%, manual dexterity deteriorated by 22% and grip strength fell by approximately 13%. In the heat, average heart rates were 157 (19) b.min<sup>-1</sup>, oxygen consumption averaged 30.62 (7.83) mL.kg<sup>-1</sup>.min<sup>-1</sup>, and average sweat loss was 0.83 (0.78) L.

### CONCLUSIONS

It is concluded that FR in both cold and hot conditions represent significant, but different, challenges. In the cold, technicians may be incapacitated by peripheral cooling, in the heat, they may be incapacitated by heat-related exhaustion. Further work will determine safe working practices and associated Physical Employment Standards for flood technicians.

## EXERTIONAL FORCES REQUIRED TO STAND-UP FOLLOWING A FALL ON MILITARY CROSS-COUNTRY SKIS

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### INTRODUCTION

Ski-marching is a unique Royal Marines Ground Close Combat task, where individuals will inevitably fall over at some point, so it is important that they are able to stand back up and regain movement quickly. This case-study measured the forces required to stand-up when on skis following a fall on level ground.

### METHODS

One ski-march qualified man (stature 1.81 m; clothed mass 101 kg) completed the case-study, wearing in-service ski-march boots, skis and holding ski poles. Lying on their side with skis braced against a block fitted to an embedded tri-axial force platform (Kistler 958, Kistler Instruments, UK), and ski poles positioned on an adjacent force platform, the participant stood up using a combination of movements from the upper and lower body (termed the “manoeuvre”). Force data were sampled at 1000 Hz, normalised to total Body Weight (BW) and reported as multiples of BW.

### RESULTS

The lower body force applied over the manoeuvre (~10 s from prone to stable standing) was predominately vertical (Fz), producing a peak force of 1.04 BW. Force reduced in the middle of the movement due to the hip and knee flexion and the ankle dorsiflexion required to shift the participant’s centre of mass over their base of support and coincided with the point of greatest contribution from the upper body. This point is where the participant reaches a stable and balanced stance allowing efficient use of the legs (predominately Fz) to stand-up. The upper body exerted force both vertically and forwards and backwards (Fx). The Fx forces (peak 0.35 BW) were exerted negatively, backwards and away from the participant to push their centre of mass over their base of support, with the positive Fz force (peak 0.63 BW) lifting the participant upwards. The total peak lower body force was 0.97 BW (Fz 0.63 vs. Fx 0.35 BW) resulting in an arc trajectory of the torso back to a stable standing position.

### CONCLUSIONS

This study indicates that this is a demanding manoeuvre requiring a coordinated contribution from both the lower and upper body resulting in a cumulative peak force of ~1.8 BW. This cumulative force is likely to be as high, if not higher when wearing a full combat load (i.e. total ski-march weight ≥40 kg) which will usually include a heavy backpack.

## THEMATIC POSTER SESSION 2B – DEVELOPEMT OF PES 1

### COMPARING LEVELS OF FITNESS OF POLICE OFFICERS BETWEEN TWO UNITED STATES LAW ENFORCEMENT AGENCIES

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#### INTRODUCTION

Police officers are required to perform tasks that are highly varied in terms of type and duration. To perform these duties safely and effectively, it is important for an officer to have sufficient muscular power, strength and endurance, and cardiovascular fitness. However, it may be assumed that as aspects of policing duties may be similar across different cities, counties, and states, all police departments and their officers may have the same levels of fitness. The aim of this study was to investigate whether fitness levels between police officers from two different United States law enforcement agencies (LEA) would be similar.

#### METHODS

Retrospective data were collected from two U.S. LEAs. LEA1 included 79 incumbent officers ( $\sigma = 72$ , mean age =  $39.43 \pm 8.28$  years, mean weight =  $87.46 \pm 11.59$  kg;  $\text{♀} = 7$ , mean age =  $38.14 \pm 3.84$  years, mean weight =  $62.72 \pm 4.49$  kg), while LEA2 had 319 incumbent officers ( $\sigma = 315$ , mean age =  $37.9 \pm 7.71$  years, mean weight =  $88.84 \pm 12.93$  kg;  $\text{♀} = 4$ , mean age =  $32.0 \pm 7.07$  years, mean weight =  $73.14 \pm 18.36$  kg). The data of officers from both agencies included: age, weight, vertical jump, 1-minute push-up, 1-minute sit-up, 2.4 km run (LEA 1) and 20-meter Multi-Stage Fitness Test (LEA 2). Independent samples t-tests were used to compare anthropometric and fitness data by whole cohorts and by male cohorts. Female cohorts were excluded from analysis given their small sample sizes ( $n = 7$  and  $n = 4$  respectively). Alpha levels were set at 0.05.

#### RESULTS

Officers from LEA1 weighed significantly less and performed significantly better than officers from LEA2 on all fitness measures. When comparing male officers alone, there was no statistical difference in age and weight; nonetheless, officers from LEA1 significantly outperformed officers from LEA2 on all fitness measures.

#### CONCLUSIONS

The results from this study indicated clear differences in fitness between two different agencies from the US. This occurred despite the potential for similarity in certain law enforcement job tasks and academy training across different agencies. Based on the significant differences in officer performance found in this study, it is important for each LEA to develop fitness standards and training protocols for their officers that are contextualised to their specific populations and training needs.

## THE DEVELOPMENT OF A PREPARATORY PHYSICAL EVALUATION FOR THE SPAT-ENPQ

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### INTRODUCTION

The Quebec police academy (École Nationale de Police du Québec, ENPQ) recently implemented the Standardised Physical Abilities Test (SPAT-ENPQ), a timed circuit simulating different tasks judged critical and essential to the police profession and important to the police training. Following the development of a physical employment standard (PES), the possibility of accommodation should be addressed by the organisation. As stated by Jamnik (2013), the development of different tools to help the candidates in their physical preparation for a PES can provide accommodation. The PPE-SPAT is a low cost physical evaluation developed using a content validity approach to both estimate the performance of a candidate at the SPAT-ENPQ and identify the specific physical abilities a candidate needs to improve to increase its chances of success. The PPE-SPAT is composed of six independent tests (long jump, medball toss, grip strength, reaction time test, modified T-test, and 600-meters run) targeting the physical abilities previously identified as essential to the accomplishment of the SPAT-ENPQ. This poster focusses on the development of the PPE-SPAT.

### METHODS

41 college students from police technology program took part in our project. Our experimental protocol consisted of two experimentations. First, all participants performed the PPE-SPAT. To acquire data on the metabolic response during the 600 m run, the in-effort heart rate (HR) and post-effort lactatemia of the participants were measured. On the second experimentation, the participants performed the SPAT-ENPQ. HR and lactatemia was also measured during this experimentation.

### RESULTS

Individually, the six tests included in the PPE-SPAT showed a significant correlation ( $p < 0.001$ ) with the results at the SPAT-ENPQ. During both the 600 m run and the SPAT-ENPQ, participants showed peak HR near estimated maximal HR and elevated post-efforts lactatemia. Using the results of our participants at PPE-SPAT, a linear multiple regression model was developed to predict the performance at the SPAT-ENPQ ( $R^2 = 0.669$ ,  $F(6,40) = 11.45$ ,  $p < 0.001$ ). In addition, norm-referenced gradings were created for each of the six tests of the PPE-SPAT.

### CONCLUSIONS

Overall, our results showed that the PPE-SPAT can be a useful tool to help the candidates in their physical preparation for the SPAT-ENPQ.

## AEROBIC FITNESS ASSESSMENTS IN DEPUTY SHERIFF RECRUITS: THE 20-METRE MULTISTAGE FITNESS TEST AND 1.5-MILE RUN

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### INTRODUCTION

Aerobic fitness is often assessed during the hiring process, at the start, and throughout academy training in law enforcement recruits. The multi-stage fitness test (MSFT) is commonly used in the UK and Australia. Incorporating distances of 15-20 m, the MSFT has the advantage of providing an external pacing strategy. In contrast, in the USA the 1.5-mile run is arguably the most common aerobic assessment in law enforcement. Potential limitations of the 1.5-mile run is that recruits use an internal pacing strategy where they find a comfortable running cadence, and this assessment requires fewer direction changes. The aim of this study was to document sex differences between the 20-m MSFT (20MSFT) and 1.5-mile run in deputy sheriff recruits, and relationships between the assessments.

### METHODS

Retrospective analysis on recruits from four academy classes (196 males, 28 females) from one agency was conducted. The 20MSFT was completed prior to academy training. The 1.5-mile run was completed in the first week of academy. Between-sex comparisons in the 20MSFT and 1.5-mile run was conducted with independent samples t-tests ( $p \leq 0.05$ ). Pearson's correlations and linear regression scatter plots calculated relationships between 20MSFT shuttle score and 1.5-mile run time (the sexes were analysed separately).

### RESULTS

There were no significant between-sex differences ( $p = 0.06$ ) for the 20MSFT shuttles ( $\sigma = 63 \pm 19$ ;  $\text{♀} = 56 \pm 14$ ), but there was for 1.5-mile run time ( $p < 0.01$ ;  $\sigma = 11:21 \pm 1:16$  min:sec;  $\text{♀} = 12:22 \pm 1:06$  min:sec). 20MSFT shuttles had moderate ( $r = -0.42$ ) and large ( $r = -0.60$ ) relationships with 1.5-mile run time for males and females, respectively. The  $r^2$  values from the regression equations for males ( $r^2 = 0.18$ ) and females ( $r^2 = 0.36$ ) was relatively low.

### CONCLUSIONS

The between-sex differences in the 20MSFT appeared less than that for the 1.5-mile run, although this may have been influenced by the disparate sample size for each sex. Even with significant relationships between the assessments, the predictive relationships were low. This could be because the 20MSFT induces a higher running intensity via speed increases and greater requirement for continued direction changes, which may limit transferability between the two assessments. Further investigation of the 20MSFT is required as to its applicability to indicate academy graduation or separation, and relationships with law enforcement-specific tasks.

## **BODY FAT PERCENTAGE, FIGHT LOAD INDEX, KNEE FLEXION AND ANKLE STRENGTH ASSOCIATED WITH COMBAT FITNESS**

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### **INTRODUCTION**

Optimising tactical fitness is important for combat readiness and injury prevention, especially as women have entered ground combat Military Occupational Specialties. The purpose of this study was to assess body composition, physiological, and musculoskeletal characteristics of male and female Marines by Combat Fitness Test (CFT) cumulative performance clusters.

### **METHODS**

Anthropometric, body composition (BF%, fat and fat free mass [FM and FFM: kg], and Fight Load Index [FLI: (fight load of 36.8 kg + FM)/FFM]), physiological (maximal oxygen uptake [VO<sub>2</sub>Max: ml/min], lactate threshold [LT: %VO<sub>2</sub>Max] and anaerobic power and capacity [W]), and musculoskeletal (isokinetic strength of the knee, shoulder, torso [Nm], and isometric strength of the ankle [kg]) assessments were obtained from 294 male (M) and female (F) Marines. Hierarchical cluster analysis classified Marines based on performance of two CFT events (sec): Manoeuvre Under Fire (MANUF) and Movement to Contact (MTC). Following tests for normality, one-way ANOVA or Kruskal Wallis tests, followed by Bonferroni post-hoc tests, were used to assess characteristics across clusters and sex (alpha = 0.05).

### **RESULTS**

Two clusters (C) were chosen: C1: N = 66 F, 16 M and C2: N = 18 F, 194 M, with C2 demonstrating better performance on the MANUF and MTC. C1M and C2M were significantly taller and heavier, had greater FFM, VO<sub>2</sub>Max, anaerobic power and capacity, and knee extension, shoulder internal/external rotation, and torso rotation strength than C1F and C2F. C1F demonstrated significantly greater BF% and FLI than C1M, C2F, and C2M (25.3 ± 4.7% vs 20.5 ± 6.1%, 21.2 ± 4.2%, and 18.8 ± 6.0%, and 1.1 ± 0.1 vs 0.9 ± 0.1, 1.0 ± 0.1, and 0.8 ± 0.1, respectively). C2M demonstrated significantly greater knee flexion strength than C1F and C2F (99.5 ± 22.1 Nm vs 66.5 ± 12.5 Nm and 73.2 ± 16.5 Nm, respectively), but C1M (91.6 ± 26.3 Nm) was only significantly greater than C1F. C2M demonstrated significantly greater ankle eversion and inversion strength than C1F (30.2 ± 6.2 kg vs 26.2 ± 5.7 kg and 26.3 ± 6.3 kg vs 22.9 ± 5.1 kg, respectively).

### **CONCLUSIONS**

Women with increased BF% and increased FM and reduced FFM relative to a fighting load may have decreased performance in combat-related tasks. Knee flexion and ankle strength are important characteristics for enhanced combat fitness.

# AN AGE ADJUSTED PHYSICAL EMPLOYMENT STANDARD BONA FIDE OCCUPATIONAL REQUIREMENT CUT-SCORE FOR HIRE-TO-RETIRE POLICE POPULATIONS.

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## INTRODUCTION

Previous retrospective observational studies have demonstrated significant predictive human factors for the RCMP Physical Abilities Requirement Evaluation (PARE) were officer age but not height, weight, body mass index (BMI) or gender. Population data analysis provides us with the tools to address the inevitable functional capacity decrements of older officers. A sliding scale for age as accommodation can clarify adverse impact levels.

## METHODS

Two retrospective observation studies compared a linear best fit for mean PARE score at 5 year age brackets midpoints (22.5, 27.5, 32.4, 57.5) for Group 1 (n = 9,539; 7,716 men, 1,623 women) for 2012-15 data versus a linear regression model for all Age and PARE scores, for one best time/officer < 5:00 for Group 2 (n = 8,519; 1,212 women, 7,307 men) for 2013-16 data. Various cut scores (mins:secs) were assessed for Group 1 data for adverse impact at 80% of men's passing rate for women for: 4:00 level 1 (cadet graduation); 4:30 level 2 (age-adjusted); 4:45 level 3 (recruit entry to Depot); 5:00 level 4 (physical restriction).

## RESULTS

Group 1 linear best fit equation for mean scores at age midpoints [ $Y = 180 + (1.03 (\text{Age}))$ ] was similar to Group 2 linear regression equation of all PARE vs Age data [ $Y = 179 + (1.15 (\text{Age}))$ ], which was significant  $F_{(1,8500)} = 857.5$ ,  $p < 0.0001$  explaining 94% of variance in PARE scores. Both equations demonstrated were near a line of identity slope of about 1 s a year. In Group 1 adverse impact was seen at cut-score: level 1 at 30-34 years, level 2 at 50-54 years, level 3 at 55-59 years, level 4 at 55-59 years. Fail prevalence rates at cut-score levels: 1:30% combined, (23% men, 66% women); 2:16% combined, (11% men, 41% women); 3:11% combined (8% men, 31% women); 4:9% combined (men 6%, 24% women).

## CONCLUSIONS

With age as a significant linear predictor of PARE BFOR score some federal Canadian policing and Parks departments have adopted the age adjusted pass/fail score for PARE of 4:33 for incumbent populations as a BFOR defensible accommodation for older workers.

## THEMATIC POSTER SESSION 2C – FATIGUE AND INJURY: IMPLICATIONS FOR PES

### PREDICTION OF SHOULDER INJURIES IN SPECIAL OPERATIONS FORCES BY SHOULDER STRENGTH AND KINEMATIC CHARACTERISTICS

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#### INTRODUCTION

Upper extremity (UE) musculoskeletal injury (MSI), especially shoulder MSI's affects a large percentage of military personnel. Special Operations Forces are at a greater risk due to the greater physical demands of their military occupational specialty (MOS). To reduce UEMSI, physical assessment tools are used to examine modifiable variables to predict injury risk. In an effort to validate the prognostic value of these assessments, research has previously indicated a retrospective association between shoulder strength and kinematic variables, with the development of shoulder MSIs. However, no research has been reported prospectively. The purpose of this study was to evaluate the association of shoulder strength and kinematic screenings, with respect to the development of shoulder injuries during a one-year follow up period in United States Air Force Special Operations Command (AFSOC) Operators.

#### METHODS

140 AFSOC personnel underwent a musculoskeletal evaluation of the shoulder that included a scapular kinematic assessment and isokinetic strength testing of the scapular protractors, retractors and elevators and the external and internal rotators of the shoulder. Musculoskeletal injuries of the shoulder were prospectively monitored using medical chart reviews, 365 days following the evaluation. Separate generalised estimating equations (GEE) and simple logistic regressions were used to analyse the association between baseline predictors and development of shoulder injury.  $\alpha = 0.05$ .

#### RESULTS

Logistic regression and GEEs indicated that there was no association between scapular kinematics during humeral elevation (OR = 0.99-1.00), or shoulder muscle strength (OR = 0.47–2.3), ipsilateral strength ratios, or bilateral strength asymmetries (OR = 0.99-1.04) of the protractors, retractors, elevators, external and internal rotators of the shoulder, and the development of shoulder musculoskeletal injuries ( $p > 0.05$ ).

#### CONCLUSIONS

The results indicate that shoulder isokinetic testing and kinematic assessment lack utility as a prognostic tool for shoulder MSI. This is in direct contention with previous research, of a retrospective nature, that has indicated that these are predictors of injury. These findings indicate that changes in strength, kinematics and asymmetries may be a consequence of shoulder injury and not a predisposition for greater injury risk. Therefore, more prospective research is needed to determine effective predictors of shoulder injury risk.



## OCCUPATION CHARACTERISTICS AS PREDICTORS OF UPPER EXTREMITY INJURY IN U.S. SPECIAL OPERATIONS FORCES

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### INTRODUCTION

Musculoskeletal injury (MSI) still persists in the military, accounting for almost half of all injuries. While much attention is directed towards lower extremity and spinal regions, the upper extremity (UE) still accounts for a significant proportion of MSI. Knowledge regarding occupational characteristics is pertinent to evaluating injury risk. Establishing occupational demands and characteristics of risk are essential for defining the appropriate physical employment standard (PES) threshold values. Additionally, the range of occupational duties confounds the interpretation of current PES outcomes. Military Occupational Specialty (MOS) determines exertional demands on the SF Operator, consequently altering injury risk. Furthermore, age and years of active experience (YE) could impact the risk of UEMSI. The primary purpose of this study is to determine the risk associated with MOS, age and years of experience on the occurrence of UEMSI.

### METHODS

A prospective cohort of 139 AFSOC personnel ( $27.4 \pm 5.05$  years) consisting of combat controller (CCT), pararescue (PJ), special operations weather technician (SOWT), and special tactics operator (STO) were tested at baseline and then followed for one year, assessing medical records for upper extremity injuries. The MOS, age and YE were all recorded for each individual. Odds ratios (OR) were calculated for each individual MOS, age and YE. Age and YE were grouped into quartiles based on the sample resulting in age groups: 20-23, 23.1-24, 24.1-28, 29+, and YE groups: 0-3, 3-4, 5-8, 9+.

### RESULTS

No significant ORs were observed for individual MOS categories; CCT (1.47), PJ (2.04), SOWT (0.29), STO (0.75). No significant ORs were observed for age; 20-23 (0.73), 23.1-24 (0.72), 25-28 (0.88) 29+ (2.11). The 9+ YE group was significant, indicating greater odds of injury (OR = 2.59,  $p = 0.04$ ), as compared to other participants.

### CONCLUSIONS

The results indicate that individuals with 9+ YE have a greater likelihood of UEMSI. Although age and YE trended similarly, the lack of significance for age suggests YE as the potentially stronger predictor. Therefore, as personnel YE increases more assessments should be conducted. Additionally, the CCT and PJ MOS should undergo more assessments, as they appear to be at greater odds of sustaining an UEMSI.

## STRENGTH ASYMMETRY AND PHYSIOLOGIC CHARACTERISTICS PREDICT ANKLE MUSCULOSKELETAL INJURY IN U.S. SPECIAL OPERATIONS FORCES

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### INTRODUCTION

The most prevalent musculoskeletal injury (MSI) sub location in the lower extremity locations for U.S. Special Operations Forces is the ankle. Strength asymmetry (SA) has been indicated as a possible predictor of MSI. However, there are several methods of calculating SA with limited research elucidating the differences in predictive capabilities. Additionally, emerging research indicates that combinations of factors more accurately predict MSI. In military populations, height, body mass (BM) and aerobic capacity (AC) have all been shown to predict MSI. The purpose of this study was twofold (1) evaluate differences in SA calculations for ankle injury prediction when analysing a cohort of Air Force Special Tactics Operators (STO), (2) A determine predictive value of combined SA and physiological measurements.

### METHODS

A prospective cohort of 140 STO were tested at baseline for height, BM, body composition, eversion and inversion ankle strength and AC; and then followed for one year, assessing medical records for ankle injuries. Eight different SA calculation methods were used. The association between strength and SA at baseline and the development of ankle MSI was analysed using simple logistic regression, with separate backwards elimination logistic regression models used to evaluate the association of individual SA calculation strategies with other known predictors of MSI. Each model initially included: SA, body fat, BM, height, AC and age.

### RESULTS

None of the SA models significantly predicted ankle injury alone (OR = 0.96-2.37, p = 0.06-0.62). All eight multivariable models were significant (p = 0.011-0.002), and included SA calculations and BM or height.

### CONCLUSIONS

SA observed in the ankle alone does not predict ankle injury. In conjunction with physiological measures such as BM/height, SA can contribute to the prediction of ankle injury. Moreover, no specific SA calculation was superior to the others. While aerobic capacity did not significantly contribute to the prediction of ankle injury, it may still influence the prediction of other MSI locations and should not be eliminated from physical employment standards (PES) tests. Therefore, to identify ankle MSI risk, PES tests should include ankle strength and other physiological measures in a comprehensive battery of assessments.

# AN ERGONOMIC ASSESSMENT OF LADDER CLIMBING: KEY RISKS TO TECHNICIANS IN THE OFFSHORE WIND INDUSTRY

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## INTRODUCTION

Previous assessments on ladder climbing have focused on short duration climbs involving multiple ascents and descents. The short nature of the climbs makes it difficult to generalise the findings to Wind Technicians (WT). The aim of this ethically approved study was to undertake a detailed ergonomic assessment of ladder climbing, identifying the key risks and determine if the current assessments of fitness were appropriate for assessing ladder climbing ability.

## METHODS

Following consent, ten Novice climbers (1 = female; 9 = male) and seven WT (2 = female; 5 = male) were tested. Climbers undertook 3x120 m climbs separated by approximately 1.5 hrs. Grip strength, grip endurance and manual dexterity were measured before and after the 120 m climbs. During the climbs oxygen consumption, heart rate, muscle activation and joint movements were recorded. For the first climb WT (not novices) wore a sea survival suit; all remaining climbs were conducted in overalls, personal protective equipment and climbing harness.

## RESULTS

Grip strength, endurance and manual dexterity were significantly ( $p < 0.05$ ) impaired by ladder climbing. With multiple climbs, toe clearance from the ladder was reduced (Climb 1 – 0.0515 m; Climb 3 – 0.046 m), and participants changed their technique to reach higher (shoulder angle: Climb 1 – 117°; Climb 3 – 136°). Novices demonstrated less range of movement through the hips (Novices – 46°; WT – 58°), and higher muscle activation in the upper body (Novices – 60%; WT – 49%). Subjective feedback supported the objective data that fatigue in the forearms was the greatest limiting factor. This fatigue was noted to last several days, suggesting that cumulative fatigue could impact on performance and increase injury risk.

## CONCLUSIONS

This was the first study to examine ladder climbing over a distance of 120 m with repeated climbs throughout the day. The physical demands of ladder climbing are not adequately assessed by current fitness tests. When comparing WT to Novices it was clear that experience improved performance, reduced the physiological burden and maintained optimal movement patterns for longer. Therefore, to optimise the well-being and reduce the risk of injuries, new WT and those that climb infrequently, would benefit from a training package that focuses on climbing technique.

# TOWARDS AN UNDERSTANDING OF MENTAL FATIGUE IN THE OFFSHORE WIND INDUSTRY

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## INTRODUCTION

Offshore wind industry (OSWI) operations and maintenance (O&M) technicians face significant mental and physical challenges (e.g. vessel transfer, safety critical engineering work). In addition to these task-related challenges, technicians face rigorous shift patterns, characterised by long working days, with tide dependent start times. Exposure to these challenging conditions leaves technicians vulnerable to fatigue, which poses potential risks to safety in the short term, health, and wellbeing in the longer term. Mental fatigue is the subjective experience of tiredness and aversion to further expansion of effort. It results in impaired cognitive processing and the tendency to gravitate towards lower effort strategies. Fatigued individuals are more likely to take short cuts and bypass important safety considerations. Motivation and task engagement can moderate fatigue. However, sustained high workload is likely to negatively impact on subsequent tasks. In the OSW context, this may mean that fatigue will not seem to affect an individual in their present task (e.g. routine maintenance), but could lead to unsafe behaviour on subsequent tasks (e.g. descent from the turbine). Investigation of the stressor/fatigue relationship in the context of the OSWI is necessary to determine the high-risk aspects of technician work. The current programme of work intends to explore the causes and consequences of fatigue in this important and challenging domain.

## METHODS

The planned programme of work will employ a wide range of methods including laboratory based experimental work, qualitative work, (including questionnaires, interviews and focus groups), field-based performance data and field based sleep analysis. All empirical work will be guided by the compensatory control model of human performance and will consider the role of effort and strategy shifts in predicting performance effects.

## RESULTS

Preliminary qualitative data will be subjected to content analysis and will focus on identifying causal factors in the development of fatigue. Identification of these factors will then guide experimental and fieldwork to assess the consequences of fatigue.

## CONCLUSIONS

Considering the combination of physical and mental stressors facing O&M technicians, this research will examine the causes and consequences of fatigue in the OSWI and aims to propose practical recommendations for its management and prevention.

## THEMATIC POSTER SESSION 2D – VALIDATING PES

### THE IDENTIFICATION OF MEASUREMENT ERROR FROM RESPONSES TO CONTROL QUESTIONS EMBEDDED IN AN ONLINE SURVEY

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#### INTRODUCTION

Online surveys provide researchers with a tool to gather the opinions of a workforce in a timely and cost efficient manner. This study explored the data quality of an online subjective job task analysis survey, as well as identified and quantified the impact of measurement error.

#### METHODS

Four hundred and thirty-nine authorised firearms officers in the United Kingdom Ministry of Defence Police completed an anonymous online survey. Respondents were: age  $45 \pm 10$  years; had served for  $18 \pm 11$  years; and comprised 88% men, 9% women, 3% did not state. Respondents rated the physical demand, importance, frequency, and duration of 19 common role-related tasks on a 1 to 5 scale. Tasks reflected the essential firearms and personal safety aspects of the job. Two control tasks of indisputable low physical demand were incorporated into the survey (i.e. 'sight setting', 'strip, clean, assemble firearm'). Measurement error was identified in suspect cases that rated the physical demand of both control tasks as 3 (moderate), 4 (high), or 5 (very high physical demand) on the 1 to 5 scale. Data were analysed with and without these cases and reported as a mean, median, and mode.

#### RESULTS

One hundred and nineteen respondents (26%) prematurely dropped out of the survey, which left 320 cases for analysis. Survey item non-response occurred in 954 out of 33,600 instances (3%), which equated to  $3 \pm 8$  item non-responses per survey (out of 105 items). Twenty-two cases of measurement error were identified (7%), and when removed altered the central tendency of two (mean data), three (median data), and six (mode data) survey items (out of 285). Nine measures of central tendency decreased by one-point on the 1 to 5 rating scale, and two increased by one-point.

#### CONCLUSIONS

Strategies to minimise dropout and item non-response should be considered when administering an online subjective job task analysis survey. Control questions embedded in a survey may assist researchers to identify measurement error. It was observed that measurement error existed, but exerted little influence on the overall classification of online survey subjective job task analysis ratings.

# IMPORTANCE OF VERIFICATION WORKLOADS TO CONFIRM ATTAINMENT OF A REAL VO<sub>2</sub>MAX IN STRUCTURAL FIREFIGHTER APPLICANTS

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## INTRODUCTION

Maximal oxygen uptake ( $\dot{V}O_{2max}$ ) is routinely measured in structural firefighter applicants and physical activity interventions. During a continuous graded exercise test (GXT), common criteria are applied to confirm the attainment of a real (highest) VO<sub>2</sub>max. However, the use of these criteria to determine the  $\dot{V}O_{2max}$  value has been criticised and the utilisation of discontinuous supramaximal verification workload(s) (SVW) is suggested to be used as the new gold standard. This is particularly important for non-elite athletes who do not possess the work tolerance to consistently push themselves to supramaximal effort during a continuous incremental test. The purpose of this investigation is to compare the mean VO<sub>2</sub>max values of structural firefighter applicants attained during a continuous GXT to those attained during subsequent discontinuous SVW.

## METHODS

Participants completed the GXT and subsequent SVW. Differences between the mean VO<sub>2</sub>max values attained during the continuous GXT were compared to those attained during the discontinuous SVW using a paired t-test analysis ( $p < 0.05$ ). Logistic regression was used to examine whether the ability to attain a real VO<sub>2</sub>max value during a continuous GXT is associated with sex, body mass, or age ( $p < 0.05$ ).

## RESULTS

3,828 physically active participants (men,  $n = 3641$ ; women,  $n = 187$ ) underwent an aerobic fitness test as part of the physical fitness screening protocol for structural firefighters. Mean (95% CI) VO<sub>2</sub>max values obtained during the continuous GXT and those obtained during the SVW were 47.3 (47.1-47.5) and 51.0 (50.6-51.4) mL·kg<sup>-1</sup>·min<sup>-1</sup> respectively ( $p < 0.001$ ). The difference between these mean VO<sub>2</sub>max values (3.7 mL·kg<sup>-1</sup>·min<sup>-1</sup>) was highly significant ( $p < 0.001$ ). Of the 3,828 study participants, 20.4% ( $n = 781$ ) attained their highest VO<sub>2</sub>max value during the continuous GXT while 79.6% ( $n = 3,047$ ) required the use of discontinuous SVW. Sex, body mass or age had no significant effect on the participant's ability to attain a real  $\dot{V}O_{2max}$  during a continuous GXT.

## CONCLUSIONS

These findings support the use of SVW to confirm the attainment of  $\dot{V}O_{2max}$  in structural firefighter applicants. This is particularly important as the attainment of a real  $\dot{V}O_{2max}$  influences the success of getting a job and deriving conclusions about the effectiveness of a physical activity interventions.

# SHIPBOARD FIREFIGHTING: THE DEVELOPMENT OF AN OPERATIONAL JOB BASED SIMULATION TEST FOR ROYAL CANADIAN NAVY (RCN) MARINE TECHNICIANS

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## INTRODUCTION

The primary responsibilities of Marine Technicians (MAR Tech) are to operate and maintain highly technical propulsion, mechanical and power generation systems, enabling the ships to float, move, and fight. MAR Tech are also responsible for shipboard firefighting and damage control. While fires can occur anywhere on ship, a helicopter crash is one of the most physically demanding incidents that could occur. Canadian Forces' Directorate of Fitness Human Performance Research & Development team (HPR&D) was approached by the RCN to evaluate whether the current Firefighter Physical Fitness Maintenance Program (FF FMFP) evaluation, or the FORCE test (Fitness for Operational Requirement of Canadian Forces Employment) would be suitable as a qualification for MAR Tech.

## METHODS

Five subject matter experts (SME) participated in a focus group where the TRIAGE (Technique for Research of Information by Animation of a Group of Experts) process was used to identify essential and demanding tasks. Three tasks related to helicopter crash rescue firefighting (HCRFF) were identified as the most physically demanding. An Operational Job Based Simulation (OJBS) test circuit was developed and performance data was collected on 20 participants trained in HCRFF. A modified bookmarking process was used with SME to establish the minimum acceptable performance standard.

## RESULTS

Participants (n = 20) were asked to perform 2 trials of the OJBS, the first at what they felt was a minimally acceptable work pace, and the second at an unacceptable work pace (too slow). Six Bookmarking videos were produced based on average completion times for all components of the OJBS. Nine SME participated in the bookmarking process and consensus was reached after 3 rounds of voting. The minimum standard was set at 6:03 mins for the completion of the OJBS test. The SME then had the opportunity to try the OJBS and provide their feedback on how the test related to job demands and the selected minimum performance standard.

## CONCLUSIONS

Participants and SME are confident the developed OJBS test is an accurate representation of HCRFF. The OJBS test can only be administered at RCN training facilities as it requires specific equipment. The OJBS will be implemented in 2018 and data will be collected to monitor any adverse impact or required modifications.

# VALIDITY AND RELIABILITY OF MUSCLE STRENGTH FIELD TESTS FOR USE IN THE NORWEGIAN ARMED FORCES

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## INTRODUCTION

The Norwegian Defence Forces implemented new physical fitness tests and employment standards in 2017. Previous muscle strength tests included push-ups, sit-ups and pull-ups, which have been criticised for imposing an unfair body mass bias, in addition to having limited occupational relevance. The aim of the present study was to investigate reliability and validity of several alternative muscle strength tests proposed for use in the military.

## METHODS

Thirty-three male and female Army recruits participated in the study. Criterion-related validity was investigated using a stepwise linear regression, with the dependent variable consisting of the sum of Z-scores from DXA-measured fat free mass, fat free mass divided by total body mass, an evacuation test (pulling a 70 kg manikin 40 m) and a maximal lift and carry test. Predictor tests were standing medicine ball throw (10 kg), standing long jump, pull-ups, push-ups, sit-ups, lunges (repetitions with 22 kg) and 1 repetition maximum (RM) bench press. Reliability was determined for medicine ball throw, standing long jump and pull-ups.

## RESULTS

Medicine ball throw was the single best predictor, explaining 74% of the variation in the criterion score ( $r = 0.86$ ). The second predictor entered in the regression model was standing long jump (+6%), while the last predictor was bench press (+4%). Together, these three tests explained 84% of the variation in the criterion score. Sit-ups did not correlate significantly with the criterion score, as opposed to push-ups ( $r = 0.76$ ), lunges ( $r = 0.74$ ) and pull-ups ( $r = 0.54$ ). Test – retest intraclass correlation ranged from 0.93 to 0.96 for medicine ball throw, standing long jump and pull-ups. Coefficients of variation were 2%, 3% and 21% for the three tests, respectively.

## CONCLUSIONS

The study demonstrated that medicine ball throw and standing long jump was better predictors of performance in military relevant strength tasks and absolute and relative fat free mass, compared to tests like sit-ups and pull-ups. Push-ups and lunges also correlated well with the criterion score. Medicine ball throw and standing long jump seem to be reliable, valid and practical tests of muscle strength in soldiers.



# DEVELOPING AND VALIDATING A PHYSIOLOGICAL APTITUDE TEST FOR THE ROYAL AUSTRALIAN NAVY

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## INTRODUCTION

Six criterion occupational tasks for the Royal Australian Navy have been identified and characterised: casualty search, 15-m single-person casualty drag, two-person casualty lift-and-carry, three-person fire-hose lift, moving to and fighting a fire. The aim of this investigation was to develop valid tests that reflect the muscular strength (41-82 kg) and oxygen consumption (mean 1.5-1.8 L.min<sup>-1</sup>) demands of the criterion tasks.

## METHODS

To validate the tests, participants were recruited from two Naval bases; HMAS Creswell (N = 15, 2 females) and Cerberus (N = 19, 6 females), and completed five criterion tasks (drag, lift-and-carry, fire-hose lift, and combined hose-drag and firefighting) and criterion task-related tests (15-m drag [82 kg], 15-m lift-and-carry [41 kg], resisted vertical rope-pull [490 N], chain-drag and 5-min kneeling shoulder-press [~5 kg]). A minimum of 2-min rest was given between task and test. A rating of likeness (100 mm visual analogue scale) with respect to physical strain, between task and test was obtained from each participant immediately upon completion of each test. At HMAS Cerberus and Stirling (N = 80, 13 females), the tests were completed in series as a circuit to evaluate oxygen consumption and validate against criterion task demands. A priori threshold for test acceptance were; > 7.0 likeness rating between task and test, no significant difference ( $p > 0.05$ ) between task and test performance time or perceived exertion. Data are presented as means [95% confidence intervals].

## RESULTS

Participants at HMAS Creswell provided likeness ratings for the 15-m drag, resisted vertical rope-pull, lift-and-carry, and firefighting assessments of 6.9 [1.1], 7.1 [1.5], 5.2 [1.1], and 6.6 [0.7], respectively. The tests were redeveloped and participants at HMAS Cerberus provided likeness ratings of 8.1 [0.8], 7.8 [0.5], 7.1 [1.1] and 7.6 [0.5] respectively. In addition, there was no difference in completion time or perceived exertion between all tasks and related tests. When participants completed the validated tests as a circuit at HMAS Stirling, it was deemed acceptable with respect to mean oxygen consumption (1.6 L.min<sup>-1</sup>) and likeness (8.0 [2.2]).

## CONCLUSIONS

Physiological aptitude tests and a circuit assessment were developed and validated against the physiological strain of criterion occupational tasks performed by all Royal Australian Navy personnel posted to sea.

## THEMATIC POSTER SESSION 3A – DEVELOPMENT OF PES 2

### RUNNING MILITARY SPRINT TEST VERSUS FIELD AND WINGATE PROTOCOL: A CROSS VALIDATION STUDY

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#### INTRODUCTION

Military performance evaluation in the Portuguese Army is based on general physical tests. Recent equipment changes, increased requirement for battlefield mobility and readiness for faster, more uncertain combat has prompted whether it is justified to carry out a military sprint test to evaluate the anaerobic capacity in detriment of the existing standardised general tests.

#### METHODS

Fourteen Cadets from the Portuguese Military Academy ( $20.9 \pm 1.9$  years,  $176.7 \pm 7.4$  cm height,  $75.2 \pm 8.0$  kg weight) performed three anaerobic evaluation tests: i) WGT - standard Wingate Test (cycling), ii) RAST – Running Anaerobic Sprint Test, and iii) MST – Military Sprint Test (running with combat gear) to include a work specific test, each to measure the same physiological capacity – anaerobic power. Scores from each Test: Peak Power (PP), Average Power (AP), and Power Drop (PD) were calculated and statistically compared.

#### RESULTS

ANOVA comparisons between WGT, RAST, and MST showed significant differences in all parameters (PP, AP, and FI). Bonferroni post hoc tests found differences between WGT and MST and between RAST and MST for PP ( $701.7 \pm 32.5$  w and  $642.0 \pm 23.0$  w vs  $549.6 \pm 25.0$  w), and for AP ( $525.6 \pm 23.6$  w and  $531.9 \pm 18.9$  w vs  $427.5 \pm 19.8$  w). For PD, significant differences were detected between WGT and RAST and between MST and RAST ( $42.2 \pm 2.0\%$  and  $39.2 \pm 1.9\%$  vs  $30.0 \pm 1.7\%$ ). Pearson correlations showed high positive coefficients between RAST and MST ( $r = 0.759$ ,  $p = 0.002$ , for PP; and  $r = 0.782$ ,  $p = 0.001$ , for AP) and moderate positive coefficients between WGT and MST ( $r = 0.519$ ,  $p = 0.057$ , for PP; and  $r = 0.589$ ,  $p = 0.027$ , for MP). There were no significant correlations between protocols for PD ( $p > 0.05$ ).

#### CONCLUSIONS

The MST requires a higher initial power output at start of the test (similar to that of the gold standard WGT) than the general field form. For PP, the resistance chosen is not selected by body weight as in the standard protocol but in an absolute manner (in this case, fighting load). Regarding AP, the external resistance chosen has a functional meaning in job analysis, where the lightest gear configuration impacts anaerobic power and the mimics the speed of combat. In terms of PD - the three tests show different fatigue profiles that express different procedures for measuring anaerobic power/speed. The MST proved to be more job specific and correlates better with the standard form (WGT).

## EVALUATION OF A SIMULATION TEST FOR PREDICTING CRITERION PERFORMANCE IN A MARAUDING TERRORIST FIREARMS INCIDENT

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### INTRODUCTION

The National Ambulance Resilience Unit (NARU) works on behalf of each National Health Service (NHS) Ambulance Trust in England to strengthen national resilience and improve patient outcome in challenging pre-hospital scenarios. Specialist NHS Ambulance personnel are trained to attend marauding terrorist firearms (MTFA) incidents. However, the components of fitness or physical tests that best predict effective management of MTFA incidents have not been examined.

### METHODS

Fourteen (12 males, 2 females) NHS Ambulance personnel (mean  $\pm$  SD, age:  $41 \pm 9$  y, body mass:  $80.7 \pm 14.7$  kg height:  $1.74 \pm 0.09$  m, body fat  $21 \pm 5\%$ ) wore chest-mounted heart rate (HR) monitors and completed a battery of fitness tests including a multi-stage fitness test, agility t-test, standing broad jump (SBJ), medicine ball throw and 60 m sprint. Participants completed an MTFA task reconstruction which involved five circuits of approximately 900 m, where each circuit comprised an approach, multiple sprints, triage of casualties, casualty drags, a stretcher drag and a recovery walk. During the task reconstruction, participants wore full ballistic personal protective equipment weighing  $\sim 19$  kg. Participants also completed a shorter, indoor MTFA task simulation (MTFA-SIM) based on the criterion task but designed in an indoor, shuttle run setup. This comprised of walking, sprinting, triage and casualty drags while wearing a weighted vest to simulate body armour. Performance on the fitness tests and on the simulation (performance time) were rank-correlated (Kendall's Tau) against performance on the criterion task reconstruction.

### RESULTS

Average criterion MTFA task duration was  $01:23:59 \pm 00:15:16$  hh:mm:ss at a mean cardiovascular strain of  $82 \pm 9$  %HR max. In comparison, MTFA-SIM was completed in an average duration of  $00:16:18 \pm 00:01:55$  hh:mm:ss at  $71 \pm 13$  %HR max. Performance on MTFA-SIM demonstrated the highest correlation with completion time of the criterion task reconstruction ( $\tau = 0.72$ ), followed by relative ( $\tau = -0.58$ ) and absolute ( $\tau = -0.49$ )  $VO_2$  max and SBJ ( $\tau = -0.46$ ).

### CONCLUSIONS

An easily-replicated MTFA simulation could provide a useful physical test for assessing occupational performance of NHS Ambulance personnel for MTFA tasks. Time-effective performance on this task, as well as maintaining high aerobic capacity appear to be commensurate with criterion performance.

# POSTURAL CONTROL AND FLEXIBILITY AS A PART OF FIREFIT-SYSTEM FOR ASSESSING PHYSICAL WORK CAPACITY AMONG FIREFIGHTERS

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## INTRODUCTION

FireFit is a computer based system for the assessment, feedback and follow-up of physical work capacity of firefighters. Via online computer guidance FireFit contains all the assessments required in the Finnish national guidelines (tests of aerobic capacity, muscular strength and body composition). It contains health risk assessment before the tests in cooperation with occupational physician. Firefighting and rescue tasks demand good postural and movement control and flexibility for preventing musculoskeletal injuries and disorders. The aim of this study was to select and develop the postural control and flexibility tests as a part of FireFit system.

## METHODS

The material and methods consisted of literature search and analysis of postural and movement control and flexibility tests and training. Pilot measurements for the selected tests were performed (n = 97). A questionnaire survey was also carried out and expert workshops included.

## RESULTS

Five reliable and valid tests, which are suitable for fire- and rescue work requirements, and feasible to perform in fire stations were selected. The results of the tests are related to perceived work ability, musculoskeletal symptoms and accidents. The tests have been used in different professional groups and athletes, and they are able to show longitudinal changes. Tests are functional movement screen (FMS), functional dynamic balance test with fire protective equipment and clothing, sit and reach test, flexibility of neck and shoulder region and lateral bending of back. Proposal of postural control and flexibility tests and training for firefighters contains three parts: A) FMS was recommended to perform during periodic physical examinations in occupational health practice, B) Increasing postural control and flexibility exercises in firefighters' habitual physical exercise, especially including these exercises in warm-up and cool down phases of training sessions. C) To support training, the other tests with feedback are recommended to apply in fire stations.

## CONCLUSIONS

The proposed model of assessment, feedback and exercise will support the regular motor and flexibility exercising of firefighters. This is important for the prevention of musculoskeletal injuries and to support the work ability of firefighters. It is also important to develop the model in cooperation with rescue and occupational health care personnel.

# DEVELOPING AN OCCUPATIONAL TEST FOR A COMPLEX CARDIORESPIRATORY ENDURANCE WORK TASK

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## INTRODUCTION

Constructing a wood pillar to support a mine roof was identified as a criterion occupational task performed by Coal Mines Rescue Brigadesmen. This complex ~8 min task is performed by a team, requiring cardiorespiratory endurance ( $\dot{V}O_2$ : 1.4-1.6 L.min<sup>-1</sup>) while lifting wooden blocks (~8 kg) to a range of vertical heights (0–3.0 m) requiring various postures (crouching to reaching overhead). The aim of this investigation was to develop a valid test for this task which assessed postural, cardiorespiratory and muscular endurance aptitude.

## METHODS

A simulation (shelf-stacking) test was developed and refined using seven unskilled male participants. The 5-min test required participants to wear protective equipment (boots, mining belt and mock breathing apparatus, ~22 kg) when transferring four wood blocks (30.5 kg total) between five shelf heights (0-2.2 m) with the highest shelf requiring participants to use a step-ladder. Thus, the test, replicated the postures, height and lift mass of the criterion task. Three cadences for transfer of the wooden blocks were trailed; slow (10 s), moderate (6 s) or best cadence. Twelve Brigadesmen were recruited and performed the test at the cadence that reflected the strain of the criterion task. The physiological strain of the shelf-stacking test was confirmed and validated as a part of a physiological aptitude test circuit. Oxygen consumption ( $\dot{V}O_2$ ) was measured continuously, data presented as means.

## RESULTS

In unskilled participants the slow cadence elicited an  $\dot{V}O_2$  of 1.6 L.min<sup>-1</sup>, while the moderate and best shelf-stacking cadence elicited an  $\dot{V}O_2$  of 1.9 and 2.7 L.min<sup>-1</sup> respectively. In Brigadesmen the slow cadence elicited an  $\dot{V}O_2$  of 1.7 L.min<sup>-1</sup>, consistent with the  $\dot{V}O_2$  of the criterion task. When the aptitude test circuit was performed, the shelf-stacking test (slow cadence) elicited a mean  $\dot{V}O_2$  of 2.1 L.min<sup>-1</sup>. A rest period was introduced to the test circuit immediately prior to the shelf-stacking test, resulting in a mean  $\dot{V}O_2$  of 1.7 L.min<sup>-1</sup> at the slow cadence.

## CONCLUSIONS

A cadence-based shelf-stacking test was designed to replicate the cardiorespiratory demand, posture, lift mass and height of the criterion task. The final test was introduced as part of a validated physiological aptitude test circuit.

## A LITERATURE REVIEW TO DEVELOP EVIDENCE BASED DEFINITIONS AND METHODS FOR DOCUMENTING THE PHYSICAL DEMANDS OF JOB ROLES

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### INTRODUCTION

The physical demands of various job roles have been documented for a range of physically demanding occupations. However, there remain inconsistencies in understanding the differences between a job safety analysis, ergonomic risk analysis and a physical demands analysis and the methods used to gather and report data. We have conducted a literature review to develop standardised definitions and methodologies to document the physical demands of job tasks.

### METHODS

We have reviewed 443 peer reviewed journal articles, books, legal documents, governmental organisations and private industry. Of the documents reviewed, 207 are from peer reviewed journals, 117 are government publications, 53 are from book, 3 are standards, 7 are videos, 47 are industry documents and 11 are from industry web pages covering robotics, engineering, biomechanics, physiology, medical and rehabilitation sciences. Additional sources of information include case law and ergonomic and physical assessment methodologies. These documents were used to develop standardised and consistent definitions and methodologies for measuring and documenting data to document the physical demands of job tasks.

### RESULTS

The authoritative documents were used to develop standardised physical demand definitions, data gathering methodologies and testing procedures that are valid and reliable. This standardised process not only provides quantitative data, but also provides visual documentation of postures and environmental conditions in which tasks are performed. Examples of demand definitions include the difference between “standing” and “walking” when only one or two steps are taken during the task. Over 300 jobs have been analysed using this process.

### CONCLUSIONS

New definitions and methods to document the physical demands associated with job tasks have been derived from this literature review. These can be used by research institutions, government organisations, municipalities and companies to standardise their procedures to document the physical demands of job tasks to develop Physical Employment Standards.

## VALIDATED PHYSICAL ABILITIES TEST (VPAT) AND SEPARATION RATES AMONG LAW ENFORCEMENT ACADEMY RECRUITS

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### INTRODUCTION

Law enforcement applicants are generally required to complete mandated physical abilities tests, which often relate to general components of fitness (e.g., maximal strength, strength endurance, change-of-direction speed, aerobic fitness), prior to being hired as recruits into a training academy. Recruits that separate from academy, due to injury, physical training or academic failure, and resignation for personal reason, can incur great costs to an agency. The aim of this study was to determine differences in fitness as measured by an agency-specific test battery, referred to as the Validated Physical Abilities Test (VPAT), of recruits who graduated or separated from academy training from a law enforcement agency.

### METHODS

Retrospective analysis of recruits who graduated (GRAD = 433) or separated (SEP = 86) from seven academy classes (428 males, 91 females) drawn from the one agency was conducted. The VPAT was conducted as part of the hiring process and comprised of: number of push-ups in 60 s; number of sit-ups in 60 s; number of arm ergometer revolutions in 60 s; a simulated 75-yard pursuit run; and a 1.5-mile run. Data were combined for males and females as all need to meet the same standards in academy regardless of sex. Independent samples t-tests ( $p \leq 0.05$ ) were used to compare VPAT differences between the GRAD and SEP groups.

### RESULTS

Equal variances were assumed for all VPAT variables. GRAD performed significantly better in push-ups ( $p = 0.016$ ; GRAD =  $40 \pm 14$  repetitions; SEP =  $36 \pm 14$  repetitions), arm ergometer revolutions ( $p = 0.027$ ; GRAD =  $126 \pm 20$  revolutions; SEP =  $121 \pm 23$  revolutions), and the 1.5 mile run ( $p = 0.002$ ; GRAD =  $12:53 \pm 1:42$  min:sec; SEP =  $13:31 \pm 2:08$  min:sec). There were no significant differences between the groups for number of sit-ups ( $p = 0.079$ ; GRAD =  $40 \pm 9$  repetitions; SEP =  $38 \pm 9$  repetitions) or the 75 yard pursuit run ( $p = 0.793$ ; GRAD =  $17.65 \pm 4.17$  seconds; SEP =  $17.78 \pm 2.29$  seconds).

### CONCLUSIONS

The results from this study indicated that recruits who completed more push-ups, arm ergometer revolutions, and were faster in the 1.5-mile run were more likely to graduate academy from this agency. Superior fitness as measured by these tests prior to academy training may imbue certain factors that mitigate attrition. To potentially enhance the ability to graduate academy, deputy sheriff applicants should enhance upper-body strength and endurance and aerobic fitness before completing the hiring process.

## THEMATIC POSTER SESSION 3B – DEVELOPMENT OF PES 3

### UNDERSTANDING DEMANDS OF PATROL PATHFINDER COURSE AND THE ATTRIBUTES RELATED TO SUCCESS

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#### INTRODUCTION

The Canadian Armed Forces produces specialist soldiers for Adaptive Dispersed Operations using the Patrol Pathfinder Course. The challenge with this course has been historically high attrition rates. With the aim to produce a greater number of specialist soldiers per year, this study sought to identify characteristics related to attrition and success.

#### METHODS

The 2017 11-week course held twenty-three male candidates. Pre-course VO<sub>2</sub>max, bench press, squat, and curl ups were measured at the onset of the course. Physical and physiological demands of the course were observed and measured. Pre-course training habits and post-course perceptions were assessed with questionnaires. Physiological stress was quantified over the duration of the course using blood cortisol and testosterone levels, and validated psychological questionnaires. Measurements were compared between those who passed (PASS) and those who did not (RTU/returned to unit).

#### RESULTS

Attrition rate was 48% (11/23); 9/23 injured (3 new, 6 old), 1 failure and 1 voluntary withdrawal. Candidates manipulated and performed under a 39-46kg load, an average of 6 hrs/day, and up to 10 hours in one day for 38 of 70 days, burning up to 750 calories/hour over 5 hours. Compared to candidates in PASS Group, blood cortisol levels were consistently higher ( $p < 0.05$ ) in RTU group, as well blood cortisol was significantly different over time during the course ( $p < 0.001$ ). Testosterone levels (nmol/L) were significant ( $p < 0.004$ ) for time but not group and again reflected the stress of the course. Working memory was found to be significantly higher in PASS group ( $p = 0.008$ ). VO<sub>2</sub>max, paced 72 kg squats, curl-ups, 68 kg bench press nor completion time on a 22 km 38 kg march were associated with success. All candidates participated in a training program or military training 3-6 months prior to the course. However, 8/11 (73%) of PASS (1 did not respond) had guidance compared to 2/11 (18%) of RTU.

#### CONCLUSIONS

Ability to handle stress and high mental capacity were found to be parameters associated with success. A performance training guidance package specifically tailored (physical/mental) to reduce attrition and improve success, will be assessed in future courses.



## USING A PHYSICAL EMPLOYMENT STANDARD TO PREDICT CARDIORESPIRATORY FITNESS – BLENDING OPERATIONAL READINESS AND HEALTH RISK

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### INTRODUCTION

The annual FORCE (Fitness for Operational Requirement of Canadian Forces Employment) evaluation (4 task simulations) predicts performance for the physical employment standard (PES) for the Canadian Armed Forces (CAF). To encourage CAF members to strive to achieve higher levels than the minimum on the FORCE evaluation, an incentive program has been developed. In addition to the vertical axis of this incentive program, which is based on performance times on the FORCE evaluation, the horizontal axis provides a health-related component that uses cardiorespiratory fitness (CRF). Using performance results from FORCE, anthropometric measures such as waist circumference (WC), height (Ht), weight (Wt) and lean body mass (LBM), as well as sex and age, may provide an opportunity for estimating health risk based on cardio-respiratory fitness (CRF). The purpose of this research was to identify a regression model for the prediction of CRF, measured as  $\dot{V}O_{2max}$ , to be used in the estimation of health risk calculation for the horizontal axis of the incentive program.

### METHODS

Participants included 195 CAF members (138 males, 57 females), 17-59 years of age, with a range of fitness and anthropometric measurements. On two separate days, participants performed 1) a maximal graded exercise treadmill test to obtain  $\dot{V}O_{2max}$  scores, and 2) a maximum effort FORCE evaluation. Participant's Ht, Wt, WC and LBM were also collected.

### RESULTS

Linear regressions were run predicting the criterion of measured relative  $\dot{V}O_{2max}$ . The predictive ability of the models improved for each of the regression metrics with the addition of more anthropometric data:  $R^2$  range: 0.72-0.76, SEE range: 3.82-4.12 mL.kg<sup>-1</sup>.min<sup>-1</sup>, % SEM range: 8.4-9.1%; %SEM falls within the 10% error range accepted for predictive tests. Predicted residual sum of squares cross validation demonstrated minimal shrinkage of the relationship suggesting stability of the models.

### CONCLUSIONS

This novel research uses a physical employment test battery (FORCE), alongside sex, age, Ht, Wt, WC and LBM to predict  $\dot{V}O_{2max}$  in healthy adults. This prediction can be used to establish a score for CRF, along with body composition to be applied to the horizontal axis of the CAF incentive program, which in turn predicts member's risk of all-cause mortality. Subsequent to this research, a gender based analysis is being conducted.

# THE DEVELOPMENT OF A REPEATED LIFT AND CARRY (RL&C) REPRESENTATIVE MILITARY TASK (RMT) FOR THE UK ARMED FORCES GROUND CLOSE COMBAT (GCC) PHYSICAL EMPLOYMENT STANDARDS.

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## INTRODUCTION

Ground Close Combat (GCC) personnel repeatedly lift and carry heavy objects, such as loading vehicles stores. This study aimed to develop a repeated lift and carry (RL&C) representative military task (RMT) to measure the physical capability to perform these tasks.

## METHODS

The RL&C RMT was developed in three phases. Phase-1: Rank-stratified focus groups (n = 80) and surveys (n = 1,495) identified the most physically demanding lift and carry (LC) tasks performed by GCC roles. Phase-2: Royal Marines, Army and Royal Air Force (RAF) Regiment personnel were observed performing LC tasks, for example changing vehicle track, and loading stores. Phase-3: A RL&C RMT was developed, compared to staged reconstructions, and assessed for reliability. Phase-3a, 130 personnel, wearing body armour, webbing and helmet (~21 kg) completed the RL&C RMT; involving lifting a 20 kg sandbag from the ground, carrying it to and from a marker 15 m away ( $\Sigma$ 30 m), placing the sandbag on a 1.45 m platform before repeating the same circuit without the sandbag. Personnel completed the circuit as many times as possible in 10 minutes, with sandbags carried recorded. Following Phase-3a, the platform height was raised to match current vehicle heights (1.49 m), the performance score changed to time to carry 20 sandbags, and the dress orders changed to include a weapon (Royal Marines, RAF Regiment) and removal of webbing (Army). Phase-3b: Reliability testing involved 92 GCC personnel completing the revised RL&C RMT twice (4-days apart). Mean bias and 95% Limits of Agreement (LoA) were used to compare completion times between test-1 and test-2.

## RESULTS

Phase-3a participants (n = 130) carried (mean  $\pm$  standard deviation)  $19 \pm 2$  sandbags in 10 minutes. Phase-3b participants (n = 57) carried the 20 sandbags in  $601 \pm 83$  seconds in test-1 and  $574 \pm 72$  seconds in test-2. There was a mean bias of -27 seconds ( $p < 0.01$ ) and 95% LoA of 86 s.

## CONCLUSIONS

The RL&C RMT improvement between test-1 and test-2 indicates two or more attempts are required to ensure a reliable performance measure which should be considered if the RMT is used as part of future GCC physical employment standards.

## DEVELOPMENT OF A SWIMMING REPRESENTATIVE MILITARY TASK FOR THE ROYAL MARINE COMMANDOS' PHYSICAL EMPLOYMENT STANDARDS

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### INTRODUCTION

The Royal Marine Commandos (RM) provide the United Kingdom Armed Forces' amphibious Ground Close Combat (GCC) capability; consequently, specific swimming-based tasks can be critical to both mission success and sea survival. The aim of this research was to develop a Swimming Representative Military Task (RMT) based on the job tasks performed by the RM. The development of the Swimming RMT was part of a wider project to develop the Physical Employment Standards (PES) for all GCC roles in the United Kingdom Armed Forces.

### METHODS

The RM Swimming RMT was devised through a three phase process. Phase-1: A rank-stratified focus group (n = 8) with RM Subject Matter Experts and a rank-stratified survey (n = 149), of serving RM personnel, identified a recovery from a fall overboard and a river crossing as physically demanding, role specific tasks. Phase-2: RM recruits (n = 46) were observed during a 30 m river crossing. A RM Military Judgment Panel also endorsed the rationale for their current Battle Swim Test (BST) to simulate recovery from a fall overboard. Based on these data a new swimming RMT was devised consisting of entering into water from a height of 3 m, swimming 30 m in fatigues whilst wearing webbing and rifle, passing equipment out of the pool, treading water and finally a timed, best effort, 30 m swim while pushing a waterproofed Bergen. Phase-3: Test-retest reliability of the Swimming RMT was assessed by 20 trained RM personnel completing the RMT on two occasions. Test completion times were compared using 95% Limits of Agreement (LoA).

### RESULTS

The best effort, 30 m river crossing completion time was  $110 \pm 29$  s and  $101 \pm 26$  s for test 1 and test 2, respectively. The times were not significantly different between tests (mean difference  $\pm$  standard deviation  $-9 \pm 25$  s,  $p = 0.13$ ) and 95% upper and lower LoA were  $-58$  s to  $40$  s.

### CONCLUSIONS

There was adequate test-retest reliability of the swimming RMT, however a large variability in individual scores was observed. Furthermore, the progressive development of this RMT ensures that it has strong content validity; making it suitable for the assessment of RM tasks that require personnel to swim whilst clothed and with personal equipment.

# THE DEVELOPMENT OF A VEHICLE CASUALTY EXTRACTION REPRESENTATIVE MILITARY TASK FOR THE BRITISH ARMY GROUND CLOSE COMBAT PHYSICAL EMPLOYMENT STANDARDS

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## INTRODUCTION

A Job Task Analysis in British Army Ground Close Combat (GCC) roles identified Vehicle Casualty Extraction (VCE) as a physically demanding task for Royal Armoured Corps and some Infantry roles. Therefore, there was a need to develop a representative military task (RMT) to measure the physical capability to perform a VCE for possible inclusion in future GCC Physical Employment Standards (PES). The aim of this research was to develop a VCE RMT for GCC personnel.

## METHODS

The VCE RMT was developed through a three phase process. Phase 1: 11 participants were observed performing 32 VCEs from 10 vehicles types involving the vertical extraction of a casualty from a turret or top hatch. These observations were used to develop a VCE RMT requiring participants to pull a Powerbag™ vertically through a hole at foot level, onto the platform they were stood on. The mass of the Powerbag™ started at 40 kg and increased in 5 kg increments up to 110 kg. Phase 2: 48 participants completed the VCE RMT and Staged Reconstructions (SR) of the VCE. Participants were asked to score how representative the VCE RMT was of the SR on a 1-6 scale (1 “not at all” to 6 “very well”). Phase 3: The Powerbags™ were replaced with plate weights attached to a rope through a pulley system, but otherwise the protocol remained the same. 29 participants completed the VCE RMT twice, two-days apart to assess its test-retest reliability. Participants that reached 110 kg were removed from analysis as their maximum performance could not be established. Maximum mass extracted by each participant for tests 1 and 2 were compared using Limits of Agreement (LoA).

## RESULTS

In Phase 2, participants' median rating of representativeness of the VCE RMT to the SR was 4, “somewhat”, and RMT performance (Powerbag™ mass) was (mean ± standard deviation) 90 ± 10 kg. In Phase 3, participants lifted a similar mass in the two tests (74 ± 8 kg vs. 75 ± 12 kg, n = 23). The mean bias between tests was not statistically significant (0.7 kg, p = 0.80; 95% LoA 24 kg).

## CONCLUSIONS

The VCE is a critical task for personnel serving in mounted GCC roles. The VCE RMT was representative of the task and reliable. Thus, VCE should be considered as a PES test. Prior to implementation, equipment, time requirement, and technique standardisation should be reviewed.

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