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ABSTRACT

PURPOSE: To develop a Physical Employment Standard (PES) for the British Royal Air Force Regiment (RAF Regt). **METHOD:** Twenty-nine RAF Regt personnel completed eight critical tasks wearing Combat Equipment Fighting Order (31.5 kg) while being monitored for physical and perceptual effort. A PES was developed using task simulations, measured on 61 incumbents. **RESULTS:** The resultant PES consists of: 1) a battlefield test involving task simulations: single lift and point-of-entry (psss/fail); timed elements (react to effective enemy fire and crawl) set at 95th performance percentile; casualty evacuation (CASEVAC) casualty drag and CASEVAC simulated stretcher carry completed without stopping. 2) a Multi Stage Fitness Test level 9.10 to assess aerobic fitness to complete a tactical advance to battle. **CONCLUSION:** The task-based PES should ensure RAF Regt personnel have a baseline level of fitness to perform and withstand the physical demands of critical tasks to at least a minimum acceptable standard.

Key words: critical tasks; physiological demands; direct task simulations; minimum standard; method of best practice.

Practitioner Summary: A Physical Employment Standard (PES) was developed for the British RAF Regiment by measuring the physiological demands of critical tasks on a representative cohort of incumbent personnel. A task-based PES should ensure that only those candidates, irrespective of gender, race or disability, with the necessary physical attributes to succeed in training and beyond, are selected.

INTRODUCTION

UK legislation mandates that employers must not expose employees to an unacceptable risk of injury (Health & Safety at Work Act, 1974), or treat them less favourably than others because of a protected characteristic such as age or gender (Equality Act 2010). To satisfy these legislative requirements it is recommended that occupations with a high physical demand (including the emergency services and the military) design, validate and implement evidence-based physical employment standards (PES). The aim of such standards is to ensure that individuals have the required capability to meet the physical demands of the job (Rayson 2000).

The Royal Air Force Regiment (RAF Regt) is the Ground Fighting Force of the RAF providing a range of Force Protection effects around the world, defending air assets and its personnel. The RAF Regt's role is physically and mentally demanding, incorporating many arduous tasks including: patrolling long distances while carrying heavy equipment; casualty evacuation; tactical advances to battle, whilst reacting to enemy fire. These activities are often undertaken over difficult terrain with little rest and in stressful situations.

Historically, the fitness of the RAF Regt has been assessed annually by the RAF Fitness Test and the Combat Fitness Test, neither of which have been demonstrated to be based on the job requirements of the RAF Regt. The Combat Fitness Test was developed for the British Army (Rayson 1998; Rayson, Holliman, & Bellyavin 2000) requiring Army Infantry to complete a 12.8 km loaded march, in a maximum time of 2 hrs, carrying 25 kg, including weapon (British Army Military Annual Training Tests and Workplace Induction Programme, issue 6, April 2014). The Combat Fitness Test may not be a suitable PES for the RAF Regt as it has not been validated against the critical tasks of the RAF Regt.

In addition to the Combat Fitness Test, RAF Regt and other RAF personnel are required to take the RAF Fitness Test annually; this measures aerobic capacity indirectly via the Multi Stage Fitness Test (Ramsbottom, Brewer, & Williams 1988) and muscular endurance by a 1-minute press-up and sit-up test. The RAF Fitness Test was introduced to evaluate the effectiveness of the RAF Fitness and Health Strategy, established in 1994 to improve the fitness and health of its personnel. A similar test, employed by the US Army, which consists of a 2-mile run, and maximum number of press-ups and sit-ups in 1-minute, correlated poorly with performance in US Army tasks (Foulis *et al.*, 2017). Military tasks also require high levels of strength, power and anaerobic endurance, which should be prioritised (Nindl *et al.*, 2016). In addition, not only is the RAF Fitness Test not linked to the physical requirements of RAF Regt personnel roles, but the adoption of different standards for both men and women, and for different age groups does not conform to equality law (Equality Act 2010), and therefore do not meet the requirements for an evidenced-based PES (Tipton, Milligan, & Reilly 2013). The aspiration is that RAF Regt personnel will be required to take the RAF Fitness Test annually in addition to the RAF Regt PES.

In September 2017, the British Government lifted the exclusion on females joining the RAF Regt. This created a requirement to develop and implement an evidence-based PES for the RAF Regt, to ensure that men and women recruited into the RAF Regt have the necessary physical fitness attributes to succeed in training and during Operations, whilst mitigating injury risk. The development of a suitable PES for the RAF Regt follows the example set by other North Atlantic Treaty Organization (NATO) Forces including the USA (Foulis *et al.*, 2017; Sharpe *et al.*, 2017), Canada (Deakin *et al.*, 2010) and Australia (Doyle *et al.*, 2011, 2012). The development of a PES is often described as a series of steps or phases (Rayson *et al.*, 1997; Rayson, 2000; Gledhill, 2000; Taylor & Groeller 2003; Tipton *et al.*, 2013; Reilly *et al.*, 2015). Although steps vary between studies the process of PES development, in a military context, can be summarised as three main phases: task analysis; physical demands analysis and fitness test design (Tipton *et al.*, 2013; Reilly *et al.*, 2015). Previous work identified the critical tasks of the RAF Regt (Blacker, Myers, & Nevola 2017; Treweek, Milligan, & Tipton 2017), which will be used to develop a task-based PES for the RAF Regt.

METHODS

As part of the PES development process, the physiological demands of the critical tasks of the RAF Regt were measured (Phase 1) and subsequently, the tasks were tested in a realistic occupatonal scenario (Phase 2). Testing took place at RAF Honington; phase 1 in September 2016 and phase 2 in December 2016. All participants had passed their most recent RAF Fitness Test and Combat Fitness Test, were medically fit to deploy and, after a full written and verbal brief, gave written informed consent. The study was approved by the Ministry of Defence Research Ethics Committee (MoDREC Protocol no. 754/MoDREC/16).

Task descriptions

1. *Tactical Advance to Battle (TAB)* **-** Individual within an 8-man section wearing Complete Equipment Fighting Order – Combat Order and carrying support arms and ammunition (31.5 kg), walk 16 km at 4.2 km.h^{-1}. 10 min rest period every hour.

2. *React to Enemy Fire (REEF)* - Individual within an 8-man section wearing Complete Equipment Fighting Order – Combat Order and carrying support arms and ammunition (31.5 kg). Assault and withdraw – conduct fire and movement over 200 m (100 m assault and 100 m withdraw) in 10 m bounds, zigzag movement, kneeling and prone positions.
3. *Crawl* - Individual within an 8-man section wearing Complete Equipment Fighting Order – Combat Order and carrying support arms and ammunition (31.5 kg), crawl 30 m at a deliberate pace. Eleven Subject Matter Experts[1] (SME), (1 x flight Lieutenant, 1 x sergeant, 1 x corporal and 8 x Senior Aircraftmen), identified a crawl as the final action of a Flight Battle Drill, prior to contact with the enemy. Although Flight Battle Drills was removed because it requires similar physical attributes to the React to Effective Enemy Fire but at a lower intensity, the crawl has unique physical fitness requirements (mobility, core and upper body strength) and was included for further analysis.
4. *Casualty Evacuation (CASEVAC) Single person drag* - Individually wearing Complete Equipment Fighting Order – Combat Order (31.5 kg), sprint to casualty 15 m away then drag casualty (casualty wearing Complete Equipment Fighting Order – Combat Order minus weapon [approx. 111 kg]), 15 m to a point of cover.
5. *CASEVAC Fireman's carry* - Individually (while still under fire), wearing Complete Equipment Fighting Order – Combat Order (31.5 kg), after removing casualty's day sack, lift with assistance a casualty weighing 95 kg, then fireman carry 100 m out of immediate danger area.
6. *CASEVAC Stretcher carry* - Team of four, wearing Complete Equipment Fighting Order – Combat Order (31.5 kg), carry a casualty wearing body armour, webbing, helmet, and weapon, weighing 99.5 kg on an Extract 2 Stretcher over difficult terrain for 1 km.
7. *Single Lift* - Individually, wearing Complete Equipment Fighting Order – Combat Order (31.5 kg) lift from ground to a height of 1.6 m on back of vehicle (MANSV) an item weighing up to 30 kg (e.g. 50 Cal-body, individual Bergen).
8. *Point-of-Entry* - Individually, wearing Complete Equipment Fighting Order – Combat Order (31.5 kg), climb over/through 1.2 m wall/window unaided.

[1] The combined experience of the SMEs met the criteria suggested by Blacklock *et al.*, (2015).

Phase 1: the physiological demands of critical tasks

Participants

Twenty-nine serving male RAF Regt personnel from an operatonal squadron (2 x Flight Lieutenants, 1 x Sergeant, 3 x Corporals, 3 x Lance/Corporals, 19 x Senior Aircraftmen and 1 x Leading Aircraftman) volunteered to take part (Table 1). All members of the squadron who were available for testing volunteered, minimising the potential for selection bias. Seventeen participants had completed at least one operational tour. All participants had passed their most recent RAF Fitness Test and Combat Fitness Test, were medically fit to deploy and, after a full written and verbal brief, gave written informed consent.

INSERT TABLE 1 HERE

Procedures

Participants were asked to undertake each of the critical tasks over four days as follows:

- Day 1 (am): Anthropometric data (mass and height) collected and details of operational experience provided; (pm) – React to Effective Enemy Fire
- Day 2: Crawl and Douglas Bag familiarisation
- Day 3: Tactical Advance to Battle
- Day 4: All CASEVAC tasks

All tasks were completed following a standardised dynamic warmup, in a standard clothing ensemble carrying full complement of equipment (known as Complete Equipment Fighting Order – Combat Order [CEFO-CO]), totalling 31.5 kg (day sack 16 kg, webbing 4.5 kg, body armour 5.4 kg, helmet 1 kg and rifle 4.5 kg). A full verbal brief was provided before each task and instruction, if needed, was provided during the task.

Measurements

Participants (in four sections) performed a 16 km loaded (31.5 kg) patrol on level terrain (metaled road and grass), over 4 hrs 28 min. Participants received 2 x 10 min breaks at 1 hr 25 min and 3 hrs 20 min and a 20 min break at 1 hr 54 min (rest periods were determined from UK Joint Service Publication 539 and SME input). Rating of Perceived Exertion (RPE) scale (Borg, 1982) (6 = no exertion at all, to 20 = maximal exertion) was used to record RPE at the first and second break and on completion of the patrol. Walking speed (determined from post-Operation reports from two RAF Regt operations containing 10000 sets of data of relevant occupational tasks) was paced at 4.2 $km.h^{-1}$ and heart rate (Polar Team Pro) was measured for the duration of the patrol. Oxygen consumption ($\dot{V}O_2$) was measured using Douglas Bag collections of 1 min at 1 km, 3 km, 5 km, 10 km and 15 km. Participants walked for several minutes at steady state prior to Douglas Bag collections. $\dot{V}O_2$ measurements were used to calculate a minimum aerobic fitness test standard. For all other critical tasks, time to completion, heart rate and RPE were recorded. Experimental equipment was calibrated prior to and on competition of each measurement.

Phase 2: Battlefield Test trial

Using the physiological demands data from Part 1 and advice from the SMEs, a direct task simulation battlefield scenario called the "Battlefield Test" was developed to be delivered in two parts. Part 1 incorporated the single lift and "point-of-entry" tasks. To assess the cumulative fatigue that could result from having to undertake several tasks in quick succession, the react to effective enemy fire, crawl and CASEVAC tasks were incorporated into a continuous test to simulate a battlefield scenario, which formed Part 2. The battlefield scenario was based on the requirement to advance on the enemy, crawl the final few metres to avoid being seen, execute the attack then withdraw, suffer a casualty, drag then carry the casualty out of the immediate danger area and evacuate by stretcher. Tasks of the Battlefield Test were the same as those analysed in Phase 1 apart from the simulated stretcher carry which was reduced form a 250 m to 50 m carry based on advice from SMEs and participant feedback.

Participants

Sixty-one serving RAF Regt personnel from an operational squadron (3 % of the RAF Regt [1 x Flight Lieutenant; 4 x Flying Officers; 6 x Corporals, 8 x Lance Corporals; 39 x Senior Aircraftmen and 3 x Leading Aircraftmen]) volunteered to attempt the Battlefield Test. All members of the squadron who were available for testing volunteered, minimising the potential for selection bias. Participant demographics are shown in Table 2. All participants were medically fit (Joint Medical Employment Standard "Medically Fit to Deploy"), completed a Self-Certificate of Health and provided written informed consent prior to testing.

INSERT TABLE 2 HERE

Procedures

A full verbal brief was given before Part 1 and Part 2 and instruction was provided, if needed, during the test (Table 3). Part 2 of the Battlefield Test was completed as a continuous test, as shown in Table 3. Participants were not permitted to smoke or consume caffeine 2 hrs before or during testing. Participants had access to food and beverages *ad lib*. Time to completion, heart rate and RPE were recorded.

INSERT TABLE 3 HERE

Task authenticity

Before each task, participants were asked: 'Have you received sufficient instruction to attempt the test?' After the task, participants were asked: 'Did the test reflect what you would do on Operations and Exercises?' and 'Do you feel the test was completed at a realistic and appropriate pace?' Participants were asked to elaborate if they answered "no" to any of the questions.

Setting the cut score

The RAF Regt Executive requested an inclusive test, thus the cut scores for the timed elements (react to effective enemy fire and crawl) are based on the 95th percentile performance scores, which excludes the bottom 5 % of test takers. The single lift and point-of-entry tests are a simple pass/fail. Due to the impracticality of including a four hour task simulation, a separate aerobic fitness test is required to ensure RAF Regt personnel are able to undertake a tactical advance to battle safely.

Data analyses

The Statistical Package for the Social Sciences (IBM SPSS 22.0 for Windows SPSS Inc., Chicago, IL.) was used for the data analyses. Checks that data were normally distributed were made using Kolmogorov-Smirnov and Shapiro-Wilk tests. For analysis of performance in the tactical advance to battle and battlefield tests, descriptive statistics were obtained to establish a measure of central tendency, means, standard deviation, range (minimum - maximum) and 95th percentile scores. To determine if mean oxygen consumption changed significantly during the tactical advance to battle, data were assessed using a one-way repeated measures ANOVA with Mauchley's test of sphericity. If a significant difference was found, paired samples t-tests were run with Bonferroni corrections and effect size calculations using Cohen's d (d) (Cohen's d = mean 1 - mean 2 / SD $_{pooled}$). Post hoc power analysis was also calculated (Field, 2013). $\dot{V}O_2$ was calculated as mL.kg^{-1}.metre^{-1} to allow for the variations in marching speed (3.80 km.h^{-1} to 4.64 km.h^{-1}).

RESULTS

Phase 1

A mean oxygen uptake of 16.2 $mL.kg^{-1}.min^{-1}$ was recorded during the 16 km tactical advance to battle (Table 4). No differences were observed in $\dot{V}O_2$ ($mL.kg^{-}1.metre^{-1}$) between the first, third, fifth or tenth km in comparison with 15 km. A meaningful significant increase in $\dot{V}O_2$ was observed at 10 km compared to the first km (0.24 [0.03] vs 0.22 [0.02] $mL.kg^{-1}.metre^{-1}$; $p = 0.002$; Cohen's d effect size (ES) 0.60; Post hoc power (PhP) = 0.92; n = 25) and 10 km compared to the third km (0.24 [0.03] vs 0.22 [0.03] $mL.kg^{-1}.metre^{-1}$; $p = 0.006$; ES 0.65; PhP = 0.85; n = 19). Significantly higher ($p = 0.013$) $\dot{V}O_2$ was reported at 5 km compared to 3 km, however low ES and power were observed. During periods of work a linear cardiac drift was observed, mean (SD) heart rate of 93 (12) $b.min^{-1}$ at 1 km to 110 (15) $b.min^{-1}$ at 16 km ($p < 0.05$) (Table 5). RPE remained the same for the first and second breaks, median (range) 7 (6 to 13), increasing to 8 (6 to 14) ($p < 0.05$) on completion of the tactical advance to battle. Of the 16 participants who had operational experience, seven declared the speed was too slow and nine declared it was about right. A $\dot{V}O_{2max}$ of 46.3 $mL.kg^{-1}.min^{-1}$ was calculated as a minimum aerobic capacity to safely complete a tactical advance to battle, equivalent to a Multi Stage Fitness Score level 9.10. This calculation (100/35 x 16.2 $mL.kg^{-1}.min^{-1}$ = 46.3 $mL.kg^{-1}.min^{-1}$) is based on research that suggests for long duration activities, lasting up to eight hours, individuals should not work at more than 35 % of their maximal aerobic capacity (Astrand, 1960; Bink, 1962, 1964).

INSERT TABLES 4 AND 5 HERE

Mean (SD) heart rates recorded during the react to effective enemy fire, crawl and CASEVAC tasks are shown in Table 6. Whilst the physiological data collected during the react to effective enemy fire, crawl and CASEVAC tasks provided a useful insight into their physiological demands, they were not used in the final analysis due to development of the PES, which incorporated the tasks into a continuous battlefield scenario.

INSERT TABLE 6 HERE

Phase 2

All participants successfully completed Part 1 of the Battlefield Test (the single lift and point-of-entry). All participants completed the casualty drag. Six participants failed the fireman's carry; three participants dropped the dummy between 30 m and 40 m and three at 50 m. Four participants failed the 34 kg jerry can carry; one participant put the can down at 20 m and three at 25 m.

The mean (SD) time to complete Part 2 of the Battlefield Test was 13 min 2.6 (53.1) s (including scheduled rest periods, mean [SD] time 4 min 55.8 [30.9] s). Mean (SD) heart rate was 171 (8) b.min^{-1} and mean (SD) peak heart rate was 184 (9) b.min^{-1}. Median (range) RPE was 18 (15-20) (very, very hard).

Figures 1a to 1c represent the frequency of individual scores for the react to effective enemy fire and crawl in 5 s bins (also called intervals or thresholds) and 10 s bins respectively. The 95th percentile pass mark is depicted by the vertical line. The mean (SD) times to complete the individual tasks of Part 2 of the Battlefield Test are shown in Table 7.

INSERT FIGURES 1A – 1C HERE

INSERT TABLE 7 HERE

Battlefield Test authenticity

All participants stated they had received sufficient instruction on how to complete the Battlefield Test and reported the weight of the Bergen to be realistic for the single lift. Fifty-nine (97%) participants declared the test was a realistic representation of their role. Two operationally experienced participants thought it was unrealistic to carry such a heavy load for the duration of the react to effective enemy fire. One of the least fit but most operationally experienced participants, who failed the 34 kg carry and took longer than anyone to complete the react to effective enemy fire and crawl, reported '*it was the most realistic fitness test he had ever attempted*.'

Seven operationally experienced participants suggested going to one knee during the react to effective enemy fire withdrawal provided the best compromise between speed of movement and exposure to enemy fire. Senior management accepted this rationale (the standard should be based on the minimum requirement) and the react to effective enemy fire withdrawal was amended accordingly. The data were collected with participants going prone so the standard is based on data with the test performed slightly differently.

Participants suggested the fireman's carry was not the best option to extricate a casualty from a firefight. A minimum of three (and preferably four) personnel were needed to assist the casualty on to the participant's shoulders. Others regarded this as not being an efficient use of manpower; winning the firefight is the priority, requiring the maximum number of personnel.

A casualty should be dragged out of immediate danger and then moved by stretcher when additional personnel become available. Also, supporting a 95 kg dummy on the shoulders puts considerable strain on the musculature of the shoulders and back and could pose an injury risk. The fireman's carry was therefore removed from the PES. The fireman's carry was removed after the data collection so the standard is based on data with the test performed slightly differently. Removing the fireman's carry could reduce fatigue of participants, making subsequent elements of the test, i.e. the simulated stretcher carry, easier.

Recommended PES

The recommended PES consists of two tests: a Battlefield Test and Multi Stage Fitness Test. The Battlefield Test was developed from the critical tasks of the RAF Regt combined into a battlefield scenario (Table 8). The timed elements i.e. react to effective enemy fire and crawl, were determined from the 95th percentile performance time of the 61 incumbents assessed undertaking the test. The Multi Stage Fitness Test standard (level 9.10) was derived from the aerobic demands of the tactical advance to battle.

INSERT TABLE 8 HERE

DISCUSSION

The aim of this study was to develop a task-based PES for the RAF Regt (Table 8). Data were collected from a representative sample of incumbent RAF Regt personnel, which allowed standards to be derived for a continuous battlefield scenario type test, employing direct task simulations. A separate aerobic fitness test is recommended to ensure RAF Regt personnel can undertake a tactical advance to battle safely.

Part 1 of the Battlefield Test includes the single lift and point-of-entry tasks, which are a simple pass/fail, and all participants completed these tasks without difficulty. The single lift weight of 30 kg is lighter than the British Army Infantry standard, whose personnel are required to lift a 40 kg Powerbag™ onto a 1.45 m platform (British Army Military Annual Training Tests and Workplace Induction Programme, issue 6, April 2014), but this is explained by different rationales. The Army standard is based on lifting an ammunition box whereas the RAF Regt standard is based on the requirement for all personnel to lift their personal Bergen onto the back of a MANSV (RAF Regt personnel carrier), 1.6 m high. The point-of-entry test should simulate climbing into a ground floor window, but the trailer was open and did not restrict movement as a window frame would. To improve the validity of the test a frame could be attached to the trailer. There are several advantages of using a trailer:

they are readily available; they can be moved around, and the raised floor provides a safe landing area, which should reduce the injury risk associated with this task.

Part 2 of the Battlefield Test includes the react to effective enemy fire, crawl and CASEVAC tasks completed as a continuous test. Physiological data were collected on participants undertaking each task separately but SMEs suggested incorporating the separate elements into a battlefield scenario would assess cumulative fatigue and improve face validity of the test. While performing critical emergency tasks on the job, workers generally transition from task to task without a break, so the circuit format is representative of on-the-job performance (Jamnik *et al.,* 2010; Jamnik, Gumieniak, & Gledhill 2013). Gumieniak *et al.*, (2018) incorporated simulations of critical physically demanding tasks into a job simulation circuit for Canadian wildland firefighters, which were sequenced and of the same duration as occurs in a typical wildland fire scenario. Undertaking tasks in quick succession presents a greater physical challenge compared to undertaking tasks individually, so the performance data collected during Phase 1 were not valid. Phase 2 measured the performance of a different representative sample of incumbent RAF Regt personnel undertaking the same tasks[2] but as part of a continuous battlefield scenario.

Part 2 of the Battlefield Test was physically demanding, reflected by high mean [SD] heart rate (171 [8] $b.min^{-1}$) and mean [SD] peak heart rate (184 [9] $b.min^{-1}$), which represented 88.6 % and 95.3 % of predicted maximum heart rate (220 - age), respectively. Participants also perceived the exercise as very physically demanding (RPE 18 [range 15-20]). A large variation was found in the time taken to complete the crawl, with the slowest person taking three times longer than the fastest. Technique was observed to be an important factor, highlighting the need to develop this skill during training. In addition, the day sack tended to "flop" from side to side, which hampered performance. This could be partly explained by participants' reluctance to wear the "spine" of the body armour, which is designed to secure the day sack, but was stated to restrict ability to get on and off the ground. Wearing the spine was not standardised because this represents the reality "on the ground."

It was not possible to directly measure individual performance of the stretcher carry so instead a jerry can carry, which has been shown to predict stretcher carry performance (Beck *et al.*, 2015), was employed to measure individual performance. To reduce fatigue stretcher

[2] The only task that changed, due to SME feedback from Phase 1 was the carry diatance of the jerry can, changed from 250 m to 50 m.

bearers regularly change position on the stretcher and therefore an individual could be required to carry the head-end of the stretcher with their non-dominant hand. To improve the face validity of the test a unilateral jerry can carry, which simulates the individual contribution of a 4-man stretcher carry, was used to assess individual stretcher carry performance. However, a unilateral 30 kg jerry can carry causes greater back muscle activation and spinal compression than a bilateral jerry can carry (McGill, Marshall, & Andersen 2013), which could increase the risk of injury associated with the 34 kg jerry can carry. To mitigate this, a strop (which stretcher bearers can use) was provided, this passed through the handle of the jerry can, behind the shoulders and held in the opposite hand, thereby distributing the weight.

Once the performance data of participants attempting the Battlefield Test had been analysed (see Figures 1a to 1c), the pass standard for the test was determined. The most objective and preferred method of determining the pass standard is by criterion referencing (Payne & Harvey 2010; Zumbo, 2016), which was used for the single lift and point-of-entry. Criterion-referenced standards are based solely on the physical demands of the job, supported by a clear rationale. The single lift requires participants to lift a 30 kg Bergen on to the back of a vehicle (1.6 m high) and the point-of-entry requires participants to climb through a 1.2 m high window frame. Both tests replicate the physical demands of the task and are supported by a clear rationale. The single lift and point-of-entry are a simple pass/fail. They were included for analysis to determine the success of participants attempting these tasks. For other tasks, although SMEs were able to define minimum performance in terms of load carried, distances travelled, weight dragged or carried *etc.* they could not identify a minimum speed of or time for the tasks.

For the timed elements of the Battlefield Test, i.e. react to effective enemy fire and crawl, the passing score (cut score) was set at the 95th percentile, which was a policy decision based on senior management's desire for an inclusive test. Kane (1994) addresses the "arbitrariness" of standard setting based on a belief that a performance standard and therefore a cut score is ultimately a policy decision. Standard setting, even when supported by a clear rationale is to a degree, ambiguous and it is not possible to identify the perfect or "correct" passing score. A more realistic aim is to demonstrate, by providing empirical evidence, that the performance standard and associated cut score are reasonable given the overall goals of the assessment programme (Kane, 1994). Setting a pass standard based solely on the statistics of a normative sample would not be defensible unless supported by other relevant information or evidence

(Zumbo, 2016). Setting the cut score at the 95th percentile statistically incorporated 95 % of the workforce used in the determination of the PES and therefore excluded the least fit individuals who were not able to complete the test to a satisfactory standard. Participants who fell within the bottom 5 %, admitted they were not fit enough for their role *and* they thought the test was a good representation of operational capabilities. This rationale was further supported by the 59 (97 %) participants (all serving RAF Regt personnel from an operationally active squadron) who attempted the Battlefield Test and declared the test was realistic.

Although time to complete the CASEVAC tasks (casualty drag and simulated stretcher carry) were recorded, SMEs could not identify a minimum speed of or time for the CASEVAC tasks and decided that a minimum performance standard should require personnel to complete the CASEVAC tasks without stopping. This rationale was supported in the case of the stretcher carry by the task description that states stretcher bearers should carry the stretcher for a minimum 50 m before changing position on the stretcher. Performance data could be used if it were decided in the future that the CASEVAC tasks should be completed in a minimum time.

This research was conducted on RAF Regt incumbents and when the research was undertaken, females were excluded from the RAF Regt. Setting the pass standard using this approach could limit employment to individuals with similar physical characteristics to incumbent (male) workers (Tipton *et al.*, 2013) and disadvantage females. In setting the standard for Canadian wildland firefighters, Gumieniak *et al.*, (2018) used performance data only from incumbent females and set the cut score at the mean plus one SD. This included 85 % of all female scores so did not result in adverse impact against females, based on the 80 % or 4/5ths rule. Under the 4/5ths rule adverse impact occurs when the pass rate of the protected group (e.g. females) is less than 80 % of the pass rate of the most successful group (Supreme Court of Canada vs. British Columbia 1999; Payne & Harvey 2010). Research is currently being undertaken to validate the Battlefield Test on a group of female military personnel. Data are also being collected on anyone who passes the Battlefield Test (applicants) but fails training for reasons related to physical fitness. This will help with the validation of the Battlefield Test or adjustments to its Pass/Fail levels.

Task simulations do not measure the aerobic fitness requirements of extended work periods or repeated emergency tasks, so it is sometimes appropriate to include a separate aerobic fitness test in addition to job simulation tests (Gledhill, 1997; Jamnik *et al.*, 2010). It would be impractical for a PES to include a direct simulation lasting more than four hours, thus a separate aerobic fitness test is recommended to ensure individuls have the aerobic capacity to safely complete a tactical advance to battle. The metabolic demand of the tactical advance to battle was found to be low (16.2 $mL.kg^{-1}.min^{-1}$) and there was no difference in $\dot{V}O_2$ between the 1st km and 15th km. These findings agree with Patton et al. (1991) who measured the metabolic demand of a 12 km loaded march at 4.0 $km.h^{-1}$ carrying 31.5 kg (similar parameters to the present study) and found no change in metabolic demand from the first km to the 12th km (14.6 $mL.kg^{-1}.min^{-1}$ to 14.9 $mL.kg^{-1}.min^{-1}$). In the present study metabolic demand increased by 9.1 % ($\dot{V}O_2$ drift) from the 1st km to the 10th km, then reduced, likely due to the 20 min rest period at 14 km. $\dot{V}O_2$ drift is an increase in metabolic demand during sub maximal exercise at a constant work rate, caused by an increase in ventilation, rise in core temperature, reduced respiratory exchange ratio (RER), reduced mechanical efficiency and muscle fatigue (Saltin & Sternberg, 1964; Dick & Cavanagh 1987; Kalis *et al.*, 1988), whose effects may be exacerbated with load carriage (Kalis *et al.*, 1988). Several studies have demonstrated $\dot{V}O_2$ drift during prolonged (> 2hrs) load carriage (Epstein et al., 1988; Patton *et al.*, 1991; Blacker *et al.*, 2009; Blacker *et al.*, 2011). The rest periods provided in the present study and in Patton et al., (1991) (10 mins every hour) may have reduced muscle fatigue and core temperature, two variables that contribute to $\dot{V}O_2$ drift (Dick & Cavanagh, 1987; Coyle & Gonzalez-Alonso, 2001) and attenuated their effects (Blacker *et al.*, 2009). Cardiovascular drift, indicated by a linear increase in heart rate from the 1st to 15th km, was likely a result of thermal stress, caused by the load and protective clothing. Cardiovascular drift is a phenomenon whereby cardiac and/or vascular responses gradually change or “drift” after approximately 10 mins to 15 mins moderate intensity exercise in a neutral or warm climate (Johnson & Rowell 1975). Cardiovascular drift is characterised by an increase in cutaneous blood flow, a reduction in stroke volume and pulmonary and systemic arterial pressures with a compensatory increase in heart rate, whilst cardiac output is maintained (Rowell, 1986). Participants wore an armoured vest (weight 5.4 kg), which has been shown to increase thermal stress (Havenith, 1999). Cheuvront *et al.*, (2008) compared the effect of wearing a protective armoured vest weighing 7.5 kg *versus* not wearing a vest, on heart rate during a 4-hour march at a constant metabolic rate. Heart rate was 7 bpm higher for the body armour condition compared to the control condition after the first hour of exercise and 19 bpm higher after four hours demonstrating that body armour not only elicits higher heart rates, but this effect may be exacerbated during prolonged marching, irrespective of load. In studies where no body armour was worn (Epstein *et al.*, 1988; Patton *et al.*, 1991) there was no increase in heart rate during loaded marching at a constant metabolic rate. Cardiovacular drift is significantly exacerbated by dehydration, which can reduce cutaneous blood flow as the body maintains pulmonary and systemic mean arterial pressures (Coyle & Gonzalez-Alonso 2001). Military personnel are susceptible to dehydration and heat injury while undertaking physically demanding tasks, often carrying load and wearing body armour.

Research suggests that for long duration activities, lasting up to eight hours, individuals should not work at more than 35 % of their maximal aerobic capacity (Astrand, 1960; Bink, 1962, 1964). A $\dot{V}O_{2max}$ of 46.3 $mL.kg^{-1}.min^{-1}$ (100/35 x 16.2 $mL.kg^{-1}.min^{-1}$), which could be measured indirectly using the Multi Stage Fitness Test (Level 9.10) (Ramsbottom *et al.*, 1988), represents a safe level of fitness for personnel to undertake a tactical advance to battle. The minimum aerobic standard increases the likelihood that personnel will not be physically exhausted at the end of a tactical advance to battle and will have sufficient reserves of energy to engage with the enemy (e.g. tactical advance to battle followed by a battlefield scenario). It is acknowledged that heavier individuals are potentially unfairly disadvantaged when aerobic capacity and load carriage are assessed using a test such as the Multi Stage Fitness Test (Bilzon, Allsopp, & Tipton 2001). In addition, whist perceived physical demand was low, perceived discomfort was high. The capability to complete a tactical advance to battle is as much to do with the "ability to endure" as "endurance" (physiological measure). Therefore, performance should not be solely based on a predictive aerobic fitness test, and the ability to carry load should also be assessed by tactical advances to battle equivalents performed during the year as part of training/competence-based assessment.

LIMITATIONS

The fireman's carry was removed and the react to effective enemy fire withdrawal was amended after data collection so the Battlefield Test standard is based on data with the test performed slightly differently. Deriving a cut score from the statistical distribution of test scores (i.e. for the react to effective enemy fire and crawl tasks) relies on the assumption that test takers, whose performance is above the proposed cut score, are performing the job at an acceptable level. There is no guarantee that, just because the test takers are employed in the role, they are performing satisfactorily (Zumbo, 2016). The PES has not been tested using females; this research was conducted on RAF Regt incumbents and when the research was undertaken, females were excluded from the RAF Regt. The PES should be validated on another sample of incumbent RAF Regt personnel and include females.

CONCLUSION

The tests presented in this report constitute the first task-based PES for the RAF Regt. An individual who passes the PES should be physically able to perform the role of a RAF Regt gunner and officer. The PES is based on the performance of incumbent RAF Regt personnel from operational squadrons and only Regt personnel who undertake the operational critical tasks detailed should undertake the recommended minimum PES. A minimum aerobic standard (Multi Stage Fitness Test level 9.10) is recommended to ensure RAF Regt personnel can safely complete a tactical advance to battle. Tests and standards should be revalidated due to changes in training or operational requirement, introduction of new equipment, or government policy. In any case, a PES should be reviewed for continued job relatedness after five to eight years and details of any changes recorded for audit purposes, including the originator, reason for review, changes made and impact of changes, e.g. to pass or injury rates (Reilly *et al.*, 2015).

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REFERENCES

Astrand I. 1960. "Aerobic Work Capacity in Men and Women." *Acta Physiological Scandinavia* 49 (169).

Beck B., G. L. Carstairs, J. N. Caldwell Odgers, T. L. A. Doyle, and K. J. Middleton. 2015. "Jerry Can Carriage is an Effective Predictor of Stretcher Carry Performance." *Ergonomics* doi: 1088074.

Bilzon J. L. J., A. J. Allsopp and M. J. Tipton. 2001. "Assessment of Physical Fitness for Occupations Encompassing Load- Carriage Tasks." *Occupational Medicine* 51: 357-361.

Bink B. 1962. "The Physical Working Capacity in Relation to Working Time and Age." *Ergonomics* 5(1).

Bink B. 1964. “Additional Studies of Physical Working Capacity in Relation to Working Time and Age.” *Proceedings of Second International Congress on Ergonomics*, Dortmund.

Blacker S., J. L. Fallowfield, J. L. J. Bilzon, and M. E. T. Willems. 2009. “Physiological Responses to Load Carriage During Level and Downhill Treadmill Walking.” *Medicina Sportiva* 13 (2): 108-124.

Blacker S., N. C. Williams, J. L. Fallowfield, and M. E. T. Willems. 2011. “The Effect of a Carbohydrate Beverage on the Physiological Responses During Prolonged Load Carriage.” *European Journal of Applied Physiology* 111 (8): 1901-1908.

Blacker S. D., S. D. Myers, and V. R. Nevola. 2017. “Development and Validation of Role Related Gender Free Physical Employment Standards for Ground Close Combat Roles in The British Ministry of Defence (MOD) – Phase 2.” *Somerset, UK, Defence Human Capability Science and Technology Centre*, p 295.

Blacklock R. E., T. J. Reilly, M. Spivock, P. S. Newton, and S. M. Olinek. 2015. Standard establishment through scenarios (SETS): a new technique for occupational fitness standards. *Work* 52(2), 375-383.

Borg G. A. V. 1982. “Psycho-physical Bases of Perceived Exertion.” *Medicine and Science in Sport and Exercise* 14(5): 377 – 381.

Cheuvront S. N., D. A. Goodman, R. W. Kenefi, S. J. Montain, and M. N. Sawka. 2008. “Impact of a protective vest and spacer garment on exercise heat-strain.” *European Journal of Applied Physiology* 102: 577 – 583.

Deakin J., R. Pelot, J. Smith, C. L. Weber. 2000. “Development and Validation of Canadian Forces Minimum Physical Fitness Standard,” Kingston, Ontario, Queens University.

Dick R. W. and P. R. Cavanagh. 1987. “An Explanation of the Upward Drift in Oxygen Uptake During Prolonged Sub-maximal Downhill Running.” *Medicine and Science in Sport and Exercise* 19 (3): 310-317.

Doyle T. L. A., D. Billing, J. R. Drain, A. Carr, D. Ham, A. Fogarty, G. Carstairs et al. 2011. “Physical Employment Standards for Australian Defence Force Employment Categories Currently Restricted to Women-Part A. Physically Demanding Trade Tasks”. *Defence Science and Technology Group.*

Doyle T. L. A., D. Billing, J. R. Drain, A. Carr, D. Ham, A. Fogarty, G. Carstairs et al. 2012. "Physical Employment Standards for Australian Defence Force Employment Categories Currently Restricted to Women-Part B. Physical Employment Assessments and Standards." *Defence Science and Technology Group*.

Foulis S. A., M. A. Sharpe, J. A. Redmond, P. N. Frykman, B. J. Warr, D. L. Gebhardt, T. A. Baker, et al. 2017. "US Army Physical Demands Study: Development of the Occupational Physical Assessment Test of Combat Arms Soldiers." *Journal of Science and Medicine in Sport* 1623.

Groeller, H., H. H. K. Fullagar, J. A. Sampson, B. Mott, C. A. Burdon, and N. A. S. Taylor. 2015. "Employment Standards for Australian Urban Firefighters Part 3: The Transition from Criterion Task to Test." *Journal of Occupational and Environmental Medicine* 57 (10): 1092–1097.

Gumieniak R., J. Shaw, N. Gledhill, and V. K. Jamnik. 2018. "Physical Employment Standard for Canadian Wildland Fire Fighters; Identifying and Characterizing Critical Initial Attack Response Tasks." *Ergonomics* doi: 10.1080/00140139.2018.1462408.

Gumieniak, R., N. Gledhill, and V. K. Jamnik. 2018. "Physical Employment Standard for Canadian Wildland Fire Fighters; Developing and Validating the Test Protocol." *Ergonomics* doi: 10.1080/00140139.2018.1464211.

Gumieniak, R., N. Gledhill, and V. K. Jamnik. 2018. "Physical employment standard for Canadian wildland firefighters: examining test–retest reliability and the impact of familiarisation and physical fitness training." *Ergonomics* doi: 10.1080/00140139.2018.1464213.

Havenith G. 1999. "Heat balance when wearing protective clothing." *Annual Occupational Hygiene* 43: 289.

Jamnik V. K., S. G. Thomas, J. F. Burr, and N. Gledhill. 2010. Construction, Validation, and Derivation of Performance Standards for a Fitness Test for Correctional Officer Applicants. *Applied Physiology Nutrition & Metabolism* 35: 59-70.

Johnson J. M. and L. B. Rowell. (1975). "Forearm Skin and Muscle Vascular Responses to Prolonged Leg Exercise in Man." *Journal of Applied Physiology* 39 (6): 920-924.

Kalis J. K., B. J. Freund, M. J. Joyner, S. M. Jilka, J. Nittolo, and J. H. Wilmore. 1988. "Effect of beta-blockade on the Drift in O2 Consumption During Prolonged Exercise." *Journal of Applied Physiology* 64 (2): 753-758.

Kane M. 1994. "Validating the Performance Standards Associated with Passing Scores". *Educational Research Review* 64: 425–461.

Knapic J. J., K. L. Reynolds and E. Harman. (2004). "Soldier Load Carriage: Historical, Physiological, Biomechanicsl, and Medical Aspects". *Military Medicine* 169 1: 45.

McGill S. M., L. Marshall and J. L. Andersen. 2013. "Low Back Loads While Walking and Carrying: Comparing the Load Carried in One Hand or in Both Hands." *Ergonomics* 56: 293-302.

Nindl B. C., B. H. Jones, S. Van Arsdale, K. Kelly and W. J. Kraemer. 2016. "Occupational Physical Performance and Fitness in Military Women: Physiological, Musculoskeletal Injury, and Optimized Physical Training Considerations for Successfully Integrating Women into Combat-Centric Military Occupations." *Military Medicine* 181. 1:50.

Patton J. F., J. Kaszuba, R. P. Mello and K. L. Reynilds. 1991. "Physiological responses to prolonged treadmill walking with external loads.." *European Journal of Applied Physiology* 63: 89–93.

Payne W. and J. Harvey 2010. "A Framework for The Design and Development of Physical Employment Tests and Standards." *Ergonomics* 53(7): 858-871.

Ramsbottom R., J. Brewer and C. Williams. 1988. "A Progressive Shuttle Run Test to Estimate Maximal Oxygen Uptake". *British Journal of Sports Medicine* 22 (4): 141-144.

Rayson M. P. 1998. "The Development of Physical Selection Procedures for the British Army. Phase 1: Job Analysis and Identification of Critical Tasks." *Contemporary Ergonomics* 393 - 397.

Rayson M. P., D. E. Holliman, and A. Bellyavin. 2000. "Development of Physical Selection Procedures for the British Army. Phase 2: Relationship Between Physical Performance Tests and Critical Tasks." *Ergonomics* 43: 73-105.

Rayson M. 2000. "The Process of Physical Fitness Standards Development". Chapter 3 Job Analysis. *In Constable, S and B. Palmer. State of the Art Report, Human Systems Information Analysis Centre.*

Rayson M. P. 2000. “Fitness for Work: the Need for Conducting a Job Analysis.” *Occupational Medicine* 50(6): 434 – 436.

Reilly T. J., D. L. Gebhardt, D. C. Billing, J. P. Greeves, and M. A. Sharp. 2015. “Development and Implementation of Evidence-Based Physical Employment Standards: Key Challenges in the Military Context.” *Journal of Strenght and Conditioning Research* 29: S28-S33.

Rowell L. B. 1986. “Human Circulation: Regulation During Physical Stress.” *Oxford University Press, New York.*

Saltin B. and J. Stenberg. 1964. “Circulatory Response to Prolonged Severe Exercise.” *Journal of Applied Physiology* 19 (5): 833-838.

Sharpe M. A., B. S Cohen, M. W. Boye, S. A. Foulis, J. E. Redmond, K. Larcom, J. R. Hydren, et al. 2017. “US Army Physical Demands Study: Identification and Validation of Physically Demanding Tasks of Combat Arms Occupations.” *Journal of Science and Medicine in Sport* 1623.

Tipton M. J., G. S. Milligan, T. J. Reilly. 2013. “Physiological Employment Standards 1. Occupational Standards: Objectively Subjective?” *European Journal of Applied Physiology* 113(10): 2435-2446.

Treweek J., G. S. Milligan and M. J. Tipton. 2017. “A Recommended Fitness Standard for the RAF Regiment.” *A Final Report of the Work Undertaken for the RAF Regiment by 22 Training Group (RAF Air Command) and Portsmouth University*.

Zumbo B. D. 2016. “Standard-Setting Methodology: Establishing Performance Standards and Setting Cut-Scores to Assist Score Interpretation.” *Applied Physiology Nutrition & Metabolism* 41: S74-S82.

Table 1. Participant demographics (height, weight, and age [n=29 males]).

	Age (Years)	Weight (kg)*	Height (cm)
Mean (SD)	28 (5.8)	82.7 (8.6)	178.6 (6.9)
Min	19	68.4	164.5
Max	40	99.1	198.5

Table 2. Participant demographics (height, weight, and age [n=61 males]).

	Age (Years)	Weight (kg) *	Height (cm)
Mean (SD)	27 (4.3)	82.7 (9.8)	178.6 (6.9)
Min	20	62.6	157.5
Max	38	108.6	195.5

* Measured in shorts and t-shirt.

Table 3. Battlefield Test procedures.

	Task	Description (Participants wore 31.5 kg CEFO-CO for all tests)	Methodology
Part 1	Single Lift	Lift a 30 kg Bergen on to the back of a MANSV, 1.6 m high	Using good technique (bent knees, straight back and head up), a 15 kg, 20 kg, 25 kg powerbag and finally a 30 kg Bergen, were lifted, in succession, onto the back of a MANSV. The test was self-paced. A rest of 30 s was permitted between each lift.
	Point-of-Entry	Climb over a 1.2 m high obstacle	Participants were asked to climb into a Landrover trailer, 1.2 m high. Participants were not permitted to use the wheel as a foot hold or step into the trailer.
Part 2	REEF Advance	Advance 100 m, in a zigzag fashion, adopting a prone position on each mat for 6 s before moving to the next mat	A 100 m course was set up with mats positioned diagonally to each other, 10 m apart. Participants advanced 100 m, adopting a prone firing position on each mat, before moving as quickly as possible to the next, when instructed (instructor shouting"Move!". After 30 s rest the participant leopard crawled 15 m, then returned, covering 30 m. Participants then withdraw 100 m, adopting a prone position on each mat (turning to 'face' the enemy) before moving as quickly as possible to the next mat, when instructed to do so. Time spent prone on the advance and withdrawal was approximately equal to the time spent moving between mats, which simulated the time for the participant's 'buddy' to move to an advanced firing position ('pepper-potting'). Instructors held stopwatches and used voice commands, e.g. "Move!" to instruct participants to move after 6 s.
	Rest	30 s	
	Crawl	Leopard crawl 30 m	
	REEF Withdrawal	Withdraw 100 m in a zigzag fashion, adopting a prone position (facing the same direction as the advance) for 6 s on each mat before moving to the next mat	
	Rest	30 s	
	Sprint to casualty	Sprint 15 m to a dummy	A 15 m course (concrete surface) was set up and a dummy weighing 111 kg (84 kg 'dummy' plus day sack 16 kg, body armour 5.4 kg, webbing 4 kg, and helmet 1.5 kg) was positioned 15 m from the start. Participants sprinted 15 m to the dummy, grabbed the handle on top of the body armour and dragged it 15 m back to the start/finish line.
	Drag Casualty	Drag the dummy 15 m	
	Rest	2 mins	
	Fireman's Carry	Dummy assisted on to shoulders then carry 100 m	A 100 m course with distance markers was set up in a hangar with a turn occurring at 50 m. To replicate the load lifted during the fireman's carry the day sack, weighing 16 kg was removed from the dummy (111 kg-16 kg = 95 kg). The dummy was assisted on to the shoulders of the participant. The dummy was then lifted off the participant's shoulders by a minimum of three people.
	Rest	1 min	
	Simulated Stretcher Carry (foot end)	Carry with dominant hand a 17 kg jerry can (with strop) 50 m	A 50 m course with a turn at 25 m was set up. Two jerry cans were filled with wet sand, one to a weight of 17 kg and one to 34 kg. Participants were asked to carry a 17 kg jerry can with strop (rifle sling) in their dominant hand. Following a 30 s rest a 34 kg jerry can was carried with a strop in the non-dominant hand for 50 m. Both carries were completed at a self-selected pace they considered representative of the task. The strop allowed the weight of the jerry can to be distributed across the body reducing the risk of an upper limb or torso injury.
	Rest	30 s	
	Simulated Stretcher Carry (head end)	Carry with non-dominant hand a 34 kg jerry can (with strop) 50 m	

Table 4. Mean (SD) speed and oxygen uptake (mL.kg^{-1}.min^{-1}) during the TAB (n=27).

	Speed (km.h^{-1})				
	1-2 km	**3-4 km**	**5-6 km**	**10-11 km**	**15-16 km**
Mean (SD)	4.1 (0.2)	4.5 (0.3)	4.2 (0.2)	4.3 (0.1)	4.4 (0.2)
	Oxygen Uptake (mL.kg^{-1}.min^{-1})				
	1-2 km	**3-4 km**	**5-6 km**	**10-11 km**	**15-16 km**
Mean (SD)	15.2 (1.7)	16.3 (2.0)	16.4 (1.9)	16.7 (1.8)	16.4 (1.4)
Min	11.6	12.9	12.9	11.6	13.6
Max	18.1	21.1	21.1	20.4	19.2

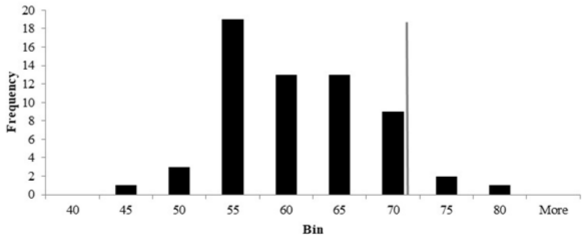
Table 5. Mean (SD) heart rates during the TAB (n=27).

	Heart rate (b.min^{-1})									
	1 km	**2 km**	**3 km**	**4 km**	**5 km**	**6 km**	**10 km**	**11 km**	**15 km**	**16 km**
Mean (SD)	93 (12)	96 (12)	97 (11)	99 (12)	99 (13)	100 (14)	107 (13)	108 (16)	110 (15)	110 (15)
Min	61	70	78	79	77	77	86	86	87	87
Max	114	117	119	124	127	133	129	138	134	138

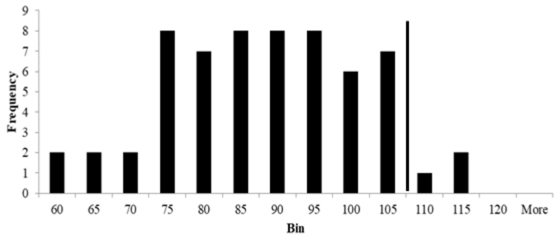
Table 6. Mean (SD) heart rates for REEF, crawl and CASEVAC tasks.

	Heart rate (b.min^{-1})					
	REEF advance	**Crawl***	**Casualty drag***	**Fireman's carry**	**17 kg carry**	**34 kg carry**
Mean (SD)	177 (10.0)	171 (9.8)	160 (12.2)	169 (11.3)	162 (16.0)	172 (13.1)
Min	161	152	136	142	132	146
Max	202	198	181	193	185	198

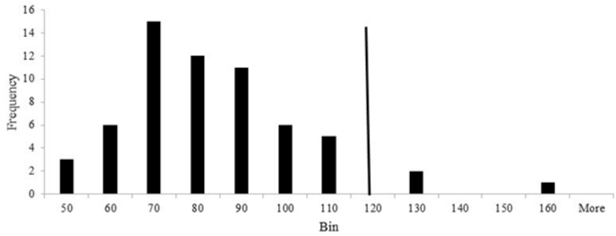
* Mean (SD) peak heart rate.



1a.



1b.



1c.

Figures 1a to 1c. Frequency plots for the REEF advance (1a), REEF withdrawal (1b) in 5 s bins and crawl (1c) in 10 s bins (n=61). The 95th percentile pass mark is depicted by the vertical line.

Table 7. Mean (SD) time to complete Part 2 of the Battlefield Test (n=61).

Time (s)	REEF advance	REEF withdraw	Crawl	Sprint to casualty	Casualty drag	Fireman's carry	17 kg Jerry can carry	34 kg Jerry can carry
Mean (SD)	58.7 (7.4)	85.7 (13.3)	77.8 (20.2)	6.5 (1.2)	20.2 (5.3)	65.1 (18.1)	23.9 (8.6)	26.9 (12.4)
Min	44.6	58.9	47.3	4.8	12.7	44.7	13.5	15.5
Max	78.9	114.8	151.7	9.6	35.3	138.9	68.4	105.4

Table 8. Recommended Battlefield Test including pass/fail scores.

	Test Description	Pass standard
Part 1	Single lift of a Bergen onto the back of a MANSV (1.6 m)	30 kg = pass
	Point-of-Entry - Climb through/over a 1.2 m window/obstacle	Pass/Fail
Part 2 Battlefield Scenario	REEF Advance – 100 m advance in 10 m zigzag bounds, individuals to adopt a prone position after each bound	Total time = 143 s Activity time = 71.5 s Each bound = 6.5 s Rest between each bound = 6.5 s
	30 s rest	
	Leopard crawl 30 m	119.3 s
	REEF Withdrawal – 100 m withdraw in 10 m zigzag bounds, individuals to adopt a kneeling position* after each bound	Total time = 173.8 s Activity time = 86.9 s* Each bound = 7.9 s Rest between each bound = 7.9 s
	30 s rest	
	CASEVAC Casualty drag - 15 m sprint to casualty followed by 15 m drag	Weight of Dummy = 111 kg Complete without stopping
	60 s rest	
	CASEVAC 50 m simulated Stretcher-Carry 17 kg (to represent carrying the foot end of a stretcher) - to be completed in the dominant hand	Complete without putting the weight down
	30 s rest	
	CASEVAC 50 m simulated Stretcher-Carry 34 kg (to represent carrying the head end of a stretcher) - to be completed in the non-dominant hand	Complete without putting the weight down

* All data were collected in the prone position but the test was changed to kneeling due to SME input and participant feedback. During testing the time difference between going prone and kneeling was determined and the timings adjusted for the test accordingly.