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Effect of a simulated tactical occupation stressor and task complexity on mental focus and related physiological parameters

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1. Introduction

Stress can be defined as a state of mental or emotional strain or tension resulting from adverse or very demanding circumstances (Selye, 1980). Stress can be experienced due to one's occupation, peers, or other daily activities that can cause strain on the body. Some types of occupations (such as industrial workers, health care professionals, pilots, professional drivers, and tactical occupations) have other individuals depending on them and some of the listed examples have other's lives in their direct responsibility; one mistake could be the difference between life and death (Apoorvagiri and Nagananda, 2013). These occupations often require the ability to react quickly to make a decision that could save another person's life (or their own) and high levels of physiological stress could have a potential effect on those decision-making skills.

A substantial challenge can be presented while completing the tasks specific to firefighting while wearing the personal protective equipment (PPE) and protective turnout gear worn by firefighters. Studies by Coca et al. (2008) and Coca et al. (2010) showed that in addition to the common experience of increased muscular strain and decreased range of motion (ROM), PPE can substantially increase the degree of heat load experienced. Due to the inherent protective layers of the turnout gear, the ability to displace body heat through evaporation is hampered and can increase the risk for a thermoregulatory emergency (McClellan and Selkirk, 2006). O'Connell et al. (1986) reported significant increases in both (HR) and oxygen consumption (VO_2) when firefighters performed 5 min of stepping exercise at 60 steps/min to simulate climbing stairs while wearing full turnout gear and related PPE weighing 39.3 kg. HR exhibited an elevation on average to 95% of HR_{max} during this workload while VO_2 was elevated to 80% of max (O'Connell et al., 1986). When taking into consideration that stairclimbing is a common occupational task for firefighters, this level of effort required of the individual can be quite taxing for an extended period of time.

Further work needs to be conducted on the effects exercise or physical exertion have on the body in regards to reaction time (RT), while also looking at task complexity and physiological stressors the body can have to respond to while making a crucial decision. This becomes especially important to occupations who must complete a strenuous physiological workload while making potential life-and-death decisions that require a quick response. Findings by Marcora et al. (2009) and more recently Zering et al. (2016) suggest that perceived exertion can be elevated during an exercise bout of a familiar intensity if it is followed by a task requiring substantial cognitive attention. Zering et al. (2016) recommended that research should be conducted on the ability to complete a brief cognitive task during a vigorous-intensity exercise or simulated high-intensity task environment. It will be important to assess if an additional physiological distractor (such as the wearing of protective firefighting gear) can lead to an impairment of the ability to respond quickly to a stimuli as well as influence RT.

A current gap in the literature exists concerning whether these simulated firefighting workloads conducted at or near upper physiological limit then leads to substantial impairments in RT along with critical thinking skills. If this does occur, the level at which it occurs and to what degree that impairment is observed with increases in workload would be important variables to define. As a firefighter performs in live-fire suppression, it is critical to understand to what degree their ability to respond quickly may be impaired by the physical work they are required to conduct to reach a potential victim of an emergency. The purpose of this study was to evaluate RT in response to a simulated firefighting occupation workload. A secondary purpose was to evaluate other exertional variables such as perceived exertion in response to a simulated firefighting occupation workload. It is hypothesized that RT will be slowed while performing a simulated firefighting occupation workload.

2. Material and methods

2.1. Participant characteristics

In this study, ten recreationally active, healthy males between the ages of 18–44 were recruited as volunteer participants. All participants

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read and signed the University's Institutional Review Board approved informed consent. The mean age of the participants was 21.6 ± 1.8 years. The mean height of the participants was 1.77 ± 0.05 m, the mean body mass of the participants was 84.9 ± 17.7 kg, and the mean body fat percentage of the participants was 12.4 ± 6.7%. The mean aerobic capacity (VO_2 max) of the participants was 49.6 ± 8.8 mL/kg/min.

2.2. Baseline testing (visit 1)

Prior to arrival for any testing session, all participants were requested to refrain from consuming caffeine for 3 h prior to arrival as well as follow their normal dietary habits and patterns, with the exception that they were requested to be at least 1 h following their most recent meal. In addition, participants were requested to refrain from any vigorous-intensity exercise or alcohol consumption in the 24 h leading up to the testing sessions. Each participant completed a 24-h dietary recall to ensure that they met the proper requirements to complete the visit on that day. The Physical Activity Readiness Questionnaire (PAR-Q) (Thomas et al., 1992) was employed during the screening process in order to screen for any potential contraindications to exercise. Participants also completed a 7-day physical activity recall questionnaire to determine physical activity status (Sallis et al., 1985). Resting HR and blood pressure were evaluated after a 5-min seated rest to ensure that resting values fell within normal limits.

After meeting all previously described entrance criteria, each participant had height and weight evaluated using standard scales. Next, body composition was estimated using a skinfold measurement technique. This involved the measurement of skinfold thickness at 7 predetermined sites on the participant's body (chest, triceps, subscapular, mid-axillary, abdomen, suprailiac, and thigh). The measurement of the sites involved a light pinching of the skin to measure the thickness of both the skin and subcutaneous fat with Lange skinfold calipers (Beta Technology, Santa Cruz, CA, USA). Each site was measured 3 times unless the difference between the measurements exceeded 3–5 mm, warranting an additional measurement to be made. The average measurement thickness at each site was then used in standardized equations to predict body fat percentage using previously published equations and protocols (American College of Sports Medicine (ACSM, 2017).

After estimation of body composition, a baseline reaction time (RT) evaluation was conducted using a timed cognitive recognition test. This RT test [color-word interference test (CWIT)] attempts to evaluate how quickly the participant can react to distracting or incorrect visual stimuli to provide a response. The ability to answer quickly as well as accurately was assessed during the CWIT. This has been described elsewhere (Muldoon et al., 1992; Steptoe et al., 1999; Steptoe et al., 2001) and involves a computerized presentation of target colored words (e.g. blue, red, green, yellow, pink) that may be printed in a different color. Using a computerized program, fifteen colored words were presented in succession one at a time at a variable timing and the succeeding word was presented following a variable gap. One complete test lasted approximately 45 s. The average RT as well as the accuracy of the responses were noted and recorded. RT was defined as the moment of response to the presented word on the screen. RT was measured using a video recording of the testing session and using a stop-watch to measure the length of time from visual presentation from the word on the screen to initial response. Accuracy is defined as the percentage (out of 100%) of responses that were correct responses to the visual presentation. This baseline visit was counted as a familiarization trial, and the same test (with varying differences between order/color of words) was conducted in certain remaining visits.

The final baseline test involved a submaximal evaluation of aerobic capacity (VO_2 max) on a treadmill. Following a brief warm-up, participants performed this VO_2 submaximal evaluation to predict VO_2 max using a modified Balke protocol (Froelicher et al., 1974). All oxygen consumption and metabolic data was assessed using a ParvoMedics TrueOne 2400 metabolic cart (Sandy, UT). No motivational encouragement was provided at any time during the testing, except for when corrective feedback was necessary to continue the performance of an exercise workload. Following completion of the submaximal VO_2 test, participants were permitted to leave.

2.3. Simulated occupational workload (visits 2–6, condition 1–5)

At least 48 h following completion of Visit 1, participants returned for Visit 2. In both Visits 2 and 3, participants completed an exercise workload that was intended to briefly simulate the physiological demands of a first responder who has a tactical-style occupation. The simulated occupational workload [Simulated Fire Stair Climb (SFSC)] attempted to mimic previously published protocols (Garner et al., 2013; O'Connell et al., 1986; Huang et al., 2009). While wearing proper testing attire, participants completed the SFSC by completing two consecutive 3-min workloads on a Matrix C7xe ClimbMill (Matrix Fitness USA, Cottage Grove, WI, USA) at a stepping rate of 60 steps/min. This SFSC is considered a standard protocol that is completed by firefighter recruits as part of the Candidate Physical Ability Test (CPAT) (Garner et al., 2013). A warm-up of 30 s at 50 steps/min was completed prior to the simulated occupational workload. After the completion of the warm-up, the participant immediately began the SFSC. During this workload, HR was measured continuously using a Polar HR monitor (Polar Electro Oy, Kempele, Finland). Rating of perceived exertion (RPE) was assessed at the end of each minute of exercise. RPE was assessed by employing Borg's 15-point (6–20) scale (Borg, 1982, 1998). The scale was depicted on a color-coded 17″ x 11″ laminated card. Participants announced their current RPE rating in number format to the investigator. Following the first 3-min SFSC bout, the participant was allowed to take a brief break, at which point blood pressure was measured. Blood pressure was measured pre-exercise, immediately following the first 3-min bout, and immediately post-exercise.

The key difference between Visits 2 & 3 was the inclusion of a weighted vest to be worn by the participant to simulate the wearing of protective clothing, a self-contained breathing apparatus (SCBA), and other fire suppression equipment typically carried by a firefighter. This weighted vest weighed a total of 34.04 kg (75 lbs), following previously published studies who have simulated a fire suppression workload (Garner et al., 2013; Huang et al., 2009; Louhevaara et al., 1994; O'Connell et al., 1986; Rhea et al., 2004).

On Visits 4 & 5, the exact same protocol and procedures were conducted with the notable exception that the previously described CWIT tests were conducted during every minute of each 3-min SFSC bout and. RT data was averaged over the 6 min of each visit and measured in milliseconds. Visit 4 involved wearing proper testing attire (without the weighted vest) and Visit 5 involved wearing the weighted vest as previously described. On a separate visit (Visit 6), the CWIT test was conducted while standing comfortably to assess ability to complete the CWIT at a resting state. Two separate 3-min standing rest bouts were conducted, in a similarly timed manner to the previously described visits. Condition order was determined through counterbalancing and each visit was separated by at least 48 h. The 5 conditions are summarized as follows:

1. SFSC – no vest (without CWIT)
2. SFSC – vest (without CWIT)
3. SFSC – no vest (with CWIT)
4. SFSC – vest (with CWIT)
5. Resting (CWIT)

2.4. Statistical analysis

A within-subjects repeated-measures ANOVA (RM-ANOVA) was used to compare all dependent variables for each condition (RT-Total, RT-correct, RT-incorrect, HR, change in blood pressure). If interactions