Work duration does not affect cortisol output in experienced firefighters performing live burn drills

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A R T I C L E   I N   P R E S S

A B S T R A C T

Work duration may affect firefighters’ stress responses. Forty-two firefighters (38 males) performed either 2 (SWD) or 3 (LWD) bouts of simulated fire suppression activity. Salivary cortisol, self-reported fear and anxiety, and perceptual thermal responses were measured. Cortisol was evaluated using area-under-the-curve calculations (Pruessner et al., 2003). Affective responses between the two conditions were compared using T-tests. Pearson product moment correlations were used to analyze the relationships between affect and change in thermal load perception. Cortisol decreased across the protocol in both groups, and no difference was found in cortisol or affect between the groups. Cortisol decreased (F5,48 = 3.43, p < 0.05) in the SWD group from a mean concentration of 40.93 ± 11.41 nmol/L to 25.07 ± 9.88 nmol/L at the end of the protocol. In the LWD group, the mean cortisol concentration decreased from 42.89 ± 11.83 to 25.07 ± 8.82 at the end of the protocol (F5,50 = 14.77, p < 0.01). Anxiety increased in the LWD (F5,47 = 5.11, p = 0.001) but not the SWD group. Fear increased in the SWD (F5,48 = 14.15, p < 0.001) and LWD group (F5,60 = 4.47, p < 0.01). The present findings suggest a moderate fear load with firefighting, which appears not to be associated with duration of work bout. Examination of more varied workbout lengths may reveal an association between anxiety and work duration. However, the work bout durations investigated in the current study comprise the range of what is practical from an occupational standpoint and the physiological capabilities of the firefighters.

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1. Introduction

Firefighting is a physically and mentally demanding occupation. Firefighters work under dangerous conditions, exposed to extreme heat, unpredictable demands, and are responsible for the lives and property of others. Fire suppression is highly strenuous work, made more challenging by the heavy personal protective clothing worn during emergencies, and induces near maximal heart rates, high core temperatures, as well as psychological disturbances (Colburn et al., 2011; Horn et al., 2011; Hostler et al., 2010; Huang et al., 2010; Kales et al., 2007; Smith et al., 2001, 2005; Smith and Petruzzello, 1998; Webb et al., 2010). These workers are prone to elevated rates of depression, anxiety disorders, and acute and posttraumatic stress disorders (Carey et al., 2011; Fullerton et al., 2004). Simulated fire scenarios offer a controlled and relatively safe research environment while still eliciting meaningful psychophysiological stress responses (Petruzzello et al., 2009).

Stressful conditions induce physiologic and psychological adaptations to maximize the chances of survival. The hypothalamic pituitary adrenal (HPA) axis is activated when threat to survival or wellbeing is faced. Adrenocorticotrophic hormone is released from the anterior pituitary gland, which stimulates the release of cortisol into the blood from the adrenal gland. The presence of cortisol in the blood stream induces altered cardiovascular and metabolic function. Cortisol influences metabolism, immunoresponses, inflammation and circulatory processes, while suppressing unnecessary bodily functions such as digestion and reproductive processes (Chrousos, 1995). Cortisol acts as its own control through a series of complex feedback mechanisms which limits the body’s
exposure to the catabolic and suppressive effects of the hormone (Tsigos and Chrousos, 2002). Dysregulation of cortisol, however, can cause disruption to metabolic, immune, and inflammatory processes (Chrousos and Gold, 1992). Disrupted HPA axis regulation has been suggested as a major factor in the development of depression (Holboer, 1999).

Humans also experience an affective response, predominantly fear and anxiety, in response to potential or known threats (Steiner, 2002). Although anxiety and fear are often used interchangeably, their experience is characterized by different circumstantial relations to threat proximity, magnitude, and perceived ability cope with the threat. Anxiety is associated with risk assessment and information gathering, when the nature or location of the threat is unknown. Anxiety is associated with vigilance and anticipatory behavior (Blanchard et al., 2001a). When the parameters of a threat are known, fear becomes the predominant emotion. The known parameters are used to inform the decision whether freezing, fleeing or fighting the threat is the best defensive response (Blanchard et al., 2011). Chronically elevated fear and anxiety responses can lead to psychopathologies such as anxiety disorders and phobias (Korte, 2001), and suppressed levels of emotional arousal can influence behavioral choices impeding chances of survival (Lerner and Keltner, 2001).

In the literature, hormonal responses to firefighting activity have variously been reported as elevated and depressed. This variation may be due to selection of the stressor. Selection of stress-invoking stimuli depends on many different factors (Greenberg et al., 2002) such as environment (laboratory versus field) and population (first responders versus naïve participants). Stress responses have been shown to vary with increasing habituation with novel stress environments invoking the highest neurochemical responses (Jean Kant et al., 1985; Korte, 2001).

Workload duration and work to rest ratio may play a part in the stress response of firefighters during fire suppression. Currently, the standards informing fire suppression practices recommend that firefighters use not more than two cylinders of breathing air before a structured recovery period. This practice influences the work duration generally performed by firefighters in a structural fire resulting in a total work period of about 40 min with a short rest interval for the cylinder change. The effect of exercise duration on cortisol response has been considered in a non-first responder population. Work durations greater than 60 min and intensities greater than 85% VO2max have each been shown to increase cortisol levels (Fernandez-Garcia et al., 2002; Wittert et al., 1991). Robson and colleagues (Robson et al., 1999) demonstrated that cortisol output was greater in a group of healthy men cycling to fatigue (duration 164 ± 23 min) at 55% VO2max when compared to 80% VO2max (duration 37 ± 19 min). These findings support those of Kindermann et al. (1982) who compared hormonal responses to a bout of prolonged treadmill exercise at lactate threshold (50 min) with a 90 s bout at 156% of exercise capacity. The results of the Kindermann and colleagues study indicated that although there was greater emotional stress, demonstrated by a steeper adrenaline regression line compared with noradrenaline in the 90-s bout but plasma cortisol concentration increased by 54% in the longer duration bout compared to 35% in the shorter bout. A third study compared the salivary cortisol output of three different workloads, 44.5%, 62.3%, and 76.0% VO2max cycling at a fixed duration of 60 min (Jacks et al., 2002). Cortisol increased in the 76.0% VO2max group compared with the two lesser intensities, which were shown not to differ from each other. Taken together, these findings suggest that exercise intensity in the 75–85% VO2max range elicits an increase in cortisol output, and that increasing workload duration influences cortisol response to a greater extent than exercise intensity.

Examining occupational factors, a review of 11 studies examining stress disorders in firefighters identified multiple workload-related risk factors that were associated with an increased likelihood of stress disorders. Of these, a higher call volume, a longer call duration were associated with anxiety (Sluiter et al., 2011). From this finding we can speculate that a longer work duration may contribute to a greater anxiety response.

Further, hormonal stress response may not always be linked to emotional stress response. Some studies reveal an inverse relationship between cortisol and acute lab-based stress exposure (Het et al., 2002; Roy et al., 2002). Other studies find no relationship between cortisol and work stressors (Maina et al., 2008) and cortisol and perceived stress (Simpson et al., 2008).

The aim of this study was to investigate the influence of exercise duration on cortisol output, fear and anxiety response in a live fire suppression scenario. We hypothesized that hormonal and affective stress responses will be greater in the long work duration (LWD) group than in the standard work duration (SWD) group.

2. Materials and methods

The protocol was approved by the University of Pittsburgh Institutional Review Board. Study participants provided written informed consent prior to the commencement of the study. Participants included 44 apparently healthy firefighters (39 male, 5 female). The mean participant age was 30.3 ± 8.3 (SD) years. The firefighters were remunerated for their participation. Participants were free of diagnosed cardiovascular disease, hypertension, did not take medications that may affect physiological or thermoregulatory responses to exercise, and did not use tobacco. During the study, one female firefighter withdrew due to scheduling conflicts. An additional male participant was excluded due to a new medical diagnosis after enrollment. The remaining 42 firefighters completed all components of the study.

Data for this study were collected over two sessions. Participants were asked to abstain from exercise, alcohol and caffeine consumption for the 12 h prior to each session. Sessions took place no fewer than seven days apart. Female participants took a urine pregnancy test before each session.

During the initial session participants were screened by a study physician. Height, mass, and body fat percentage were assessed. Maximal oxygen uptake was determined using a Bruce protocol and an open circuit metabolic measurement system (Parvomedics Inc, Utah, USA).

The second session was conducted at the Allegheny County Fire Academy training facility. On arrival, urine specific gravity (USG) was measured using a hand-held refractometer (Atago, Bellvue, WA) and a USG ≤ 1.020 was required to proceed with the protocol. Water volume consumption was standardized throughout the protocol. Female subjects were confirmed non-pregnant. During this session (Fig. 1), participants were randomized into either the SWD group (one bout each of fire suppression and roof ventilation), or LWD group (two bouts of fire suppression followed by roof

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**Abbreviations**

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<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>HPA</td>
<td>Hypothalamic pituitary adrenal</td>
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<td>VO2max</td>
<td>Maximal volume of oxygen consumption</td>
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<td>SWD</td>
<td>Standard work duration</td>
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<td>LWD</td>
<td>Long work duration</td>
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<td>SCBA</td>
<td>Self contained breathing apparatus</td>
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<td>AUC</td>
<td>Area under the curve</td>
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