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Psychophysiological relationships between a multi-component self-report measure of mood, stress and behavioural signs and symptoms, and physiological stress responses during a simulated firefighting deployment

Alexander Wolkow, PhD [a,b,c,*], Brad Aisbett, PhD [a,b], Sally A Ferguson, PhD [b,d], John Reynolds, PhD [e,1], Luana C Main, PhD [a]

[a] Deakin University, Institute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Sciences, Burwood 3125, Australia
[b] Bushfire Cooperative Research Centre, East Melbourne 3002, Australia
[c] Monash University, Faculty of Medicine, Nursing and Health Sciences, School of Psychological Sciences, Clayton 3168, Australia
[d] Central Queensland University, Appleton Institute, Wayville 5034, Australia
[e] Deakin University, Biostatistics Unit, Faculty of Health, Burwood 3125, Australia

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ABSTRACT

Physical work and sleep loss are wildland firefighting demands that elicit psychological and physiological stress responses. Research shows that these responses are statistically related which presents an opportunity to use subjective psychological questionnaires to monitor physiological changes among firefighters; an approach used extensively in sport settings. The aim of the present study was to investigate if changes in self-reported psychological factors on the multi-component training distress scale (MTDS), relate to cytokines and cortisol levels among firefighters completing three days of simulated physical firefighting work separated by an 8-h or restricted 4-h sleep each night. Each day firefighters completed the MTDS in the morning and salivary cortisol and inflammatory cytokines were measured throughout the day. When sleep restricted, firefighters demonstrated increases in MTDS factors of general fatigue, perceived stress and depressed mood that were related to elevated cytokines (TNF-α, IL-8, IL-10). Conversely, firefighters who had an 8-h sleep demonstrated a positive relationship between physical signs and symptoms and elevated IL-6, while depressed mood was inversely related to decreasing cortisol and cytokines (IL-6, TNF-α, IL-10). Findings highlight the utility of the MTDS to detect psychological changes that reflect physiological responses among firefighters. Future research that establishes thresholds for specific factors which predict health-related physiological changes, will allow fire agencies implement multi-component measures to monitor and manage the health of personnel on the fire-ground.

1. Introduction

Wildland firefighters face extended periods of physical work and restricted sleep in the line of duty (Aisbett et al., 2012; Cater et al., 2007; Phillips et al., 2015). For personnel deployed to fight campaign fires, demands involve high-intensity, intermittent physical tasks (Aisbett et al., 2007), performed across consecutive long shifts (i.e., 12 to 15-h) separated by restricted sleep opportunities (i.e., 3 to 6 h; Cater et al., 2007; Vincent et al., 2015a, b). When exposed to stressors such as physical work and sleep restriction, psychological and physiological stress responses are activated to maintain homeostasis over immune, hypothalamic-pituitary-adrenal (HPA)-axis and psychological functions (Dhabhar and McEwen, 2006; Maier and Watkins, 1998). However, severe occupational stressors can result in maladaptive physiological and psychological changes, including a deterioration in mood (Lieberman et al., 2005), dysregulated release of cortisol from the HPA-axis (Smith et al., 2005; Wolkow et al., 2015) and cytokines from the immune system (Huang and Acevedo, 2011). Prolonged changes have been implicated in the pathophysiology of cardiovascular disease (CVD), insulin resistance and depression (McEwen and Seeman, 1999; Pradhan et al., 2001; Ridker et al., 2000; Zunszain et al., 2011).

Abbreviations: AUC, area under the cortisol curve; CON, control condition; CVD, cardiovascular disease; HPA-axis, hypothalamic-pituitary-adrenal; IL, interleukin; MTDS, multi-component training distress scale; PSG, polysomnographic; REML, restricted maximum likelihood; SR, sleep restriction condition; TNF, tumour necrosis factor.

* Corresponding author at: Monash University, Faculty of Medicine, Nursing and Health Sciences, School of Psychological Sciences, Clayton 3168, Australia.
E-mail addresses: alexander.wolkow@monash.edu (A. Wolkow), brad.aisbett@deakin.edu.au (B. Aisbett), sally.ferguson@cqu.edu.au (S.A. Ferguson), john.reynolds@monash.edu (J. Reynolds), luana.main@deakin.edu.au (L.C. Main).
[1] Present affiliation: Monash University, Faculty of Medicine, Nursing and Health Sciences, Melbourne 3004, Australia.

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Stress-induced changes in psychological responses (e.g., mood) are closely related to, and possibly influence physiological processes (e.g., cytokines and cortisol; Kemeny, 2007; Marsland et al., 2007; Wright et al., 2005) via a bi-directional communication network between the brain, HPA-axis and immune system (Maier, 2003; Maier and Watkins, 1998). In addition, research shows how inflammatory and hormonal responses may signal the brain and have an effect over changes in mood, behaviour and cognition (Maier, 2003; Maier and Watkins, 1998; Slavich and Irwin, 2014). However, the potential utility of self-report measures to reflect and monitor firefighters' immune and hormonal responses on the fire-ground presents as a novel application of the subjective load monitoring approach adopted in sport settings (Saw et al., 2015, 2016). Compared to collecting and analysing biomarkers, monitoring these responses with self-report measures of mood, stress and behavioural signs and symptoms represents a less invasive and more practical option for fire agencies.

In physically demanding sport, the use of subjective measures of recovery-stress state and training load by Brink et al. (2010) and Anderson et al. (2003) respectively, have been related to incidents of injury and illness among soccer (Odds ratio 1.01 to 2.59) and basketball players ($r = 0.675$). Growing support for use of self-report measures as low cost monitoring tools to gauge athletes' physiological responses and mitigate injury and illness have resulted in their widespread application to diverse sporting contexts (Saw et al., 2016; Taylor et al., 2012). Among the tools, self-report measures employing a multi-component (e.g., mood, stress, behavioural signs and symptoms) approach are predictive, user friendly and more informative than those capturing single psychological constructs (Kellmann, 2010; Main and Grove, 2009; Saw et al., 2015). Accordingly, multi-component scales are frequently utilised in sport contexts and their relationship with physiological responses examined. For example, Main et al. (2010) investigated the relationship between inflammatory cytokine levels and self-report measures of overload in rowers completing an 8-week training course using the multi-component training distress scale (MTDS). Multiple relationships were identified between factors on the MTDS and cytokines (Main et al., 2010) that previous studies have had to use different, single construct tools to detect (Robson-Ansley et al., 2009; Wolkow et al., 2016), highlighting the convenience and breadth of the MTDS which includes the factors; depressed mood, vigour, physical signs and symptoms, sleep disturbance, perceived stress and general fatigue.

Despite success using a psychophysiological approach in athlete load monitoring contexts, limited research has investigated the ability of subjective measures to reflect stress-related physiological changes in occupational settings, such as firefighting. In our recent work (Wolkow et al., 2016), an increase in subjective fatigue was positively related to increased IL-6, TNF-α, IL-10 and cortisol among sleep restricted firefighters performing multiple days of physical work. Using a separate mood questionnaire (Mood Scale II; Thorne et al., 1985), we also found an increase in mood dimensions related to negative affect (e.g., fear) among sleep restricted firefighters were associated with a rise in TNF-α (Wolkow et al., 2016). Subjective pain ratings during 12 nights of sleep restricted to 4-h were also strongly associated with elevated IL-6 in a study by Haack et al. (2007). However, previous findings are inconsistent, with other studies reporting no association between negative mood and cortisol during physical work (Filaire et al., 2004) or sleep loss (Bouhuys et al., 1990). Although insights are gained from examining physical work or sleep loss in isolation, fighting wildfires exposes personnel to a combination of these stressors (Aisbett et al., 2012). Accordingly, determining the impact of sleep restriction while performing simulated physical firefighting work on psychophysiological responses is needed.

Physical work and sleep loss related stressors that elicit psychophysiological relationships in occupational settings highlight the potential usefulness of sport-based, multi-component questionnaires to monitor physiological changes among firefighters. Therefore, the aim of the current study was to investigate how possible changes in MTDS factors related to cytokine and cortisol levels among firefighters completing multiple days of simulated physical firefighting work, with and without restricted sleep. We hypothesised that when sleep restricted, firefighters performing physical work would display adverse subjective psychological responses across a range of measures (depressed mood, general fatigue, perceived stress, physical signs and symptoms, sleep disturbances, vigour) that related to elevations in cytokines and cortisol.

2. Methods

2.1. Participants

Wildland volunteer and career firefighters were recruited from state and territory-based fire agencies throughout Australia to maximise the generalisability of potential findings to rural firefighters nationally. For statistical purposes, participants were matched by sex, age and body mass index (BMI; $p > 0.05$; Table 1), and randomly allocated to either a control (CON) or sleep restriction (SR) condition. All participants completed a general health questionnaire to screen and subsequently exclude anyone diagnosed with any form of heart disease, diabetes, respiratory and/or sleep disorder. Furthermore, participants completed pre- and post-testing questionnaires to record injuries or illnesses occurring directly prior, or during the study that could influence the stress markers measured. One firefighter in the SR condition withdrew due to injury and therefore, a final sample of 17 firefighters in the SR group and 18 firefighters in the CON group completed the study and were included in the final analyses. The study was approved by the institutions' Human Research Ethics Committee and written informed consent was provided by all participants.

2.2. Protocol

Prior to commencing data collection, all participants completed a familiarization session that covered the physiological measures, physical work tasks and self-report questionnaire. Following this, participants had an adaptation night (8-h sleep opportunity) in the testing environment. Participants in both conditions were then tested over a three-day and two-night simulated fire-ground tour that reflected the typical length of a fire-ground deployment. On each of the two nights, participants in the CON condition had an 8-h sleep opportunity (i.e., 22:00–06:00), while participants in the SR condition had their bed time delayed resulting in a 4-h sleep opportunity (i.e., 02:00–06:00; Fig. 1). Participants in the SR condition performed sedentary leisure activities (e.g., watching movies, playing cards etc.) until the delayed bedtime. The sleep restriction duration was based on Australian wildland firefighters' average sleep obtained between shifts on the fire-ground based on Cater et al. (2007) and verified by Vincent et al. (2015b). After the testing period, all participants had an 8-h sleep to facilitate recovery prior to leaving the testing venue (Fig. 1). The testing environment for both conditions was maintained between 18 and 20 °C to reflect moderate temperatures in which firefighting duties are often completed (Raines et al., 2012).

Table 1
Characteristics of participants in each condition (mean ± standard deviation).

Characteristic	CON (n = 18)	SR (n = 17)
Age (years)	39 ± 16	39 ± 15
Male:Female (n)	15:3	15:2
Weight (kg)	85.1 ± 17.7	93.8 ± 20.2
Height (cm)	178.1 ± 7.7	177.8 ± 7.4
BMI (kg/m^2)	26.8 ± 5.0	29.6 ± 5.5
Firefighting experience (years)	9 ± 9	10 ± 6

Note: BMI = Body Mass Index.