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The accuracy of subjective measures for assessing fatigue related decrements in multi-stressor environments

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A B S T R A C T

It has become increasingly common for rural fire-fighting agencies to encourage their volunteers to control and monitor their own levels of fatigue and performance abilities. Yet, the accuracy of subjective evaluations, especially during exposure to multi-stressor working conditions similar to those faced by rural fire-fighters has yet to be examined. A total of 91 rural fire-fighters took part in a 4-day/3-night live-in study that simulated a fire-ground tour. Fire-fighters were required to perform a total of 14 circuits that involved intermittent intense physical work, whilst exposed to heat, sleep deprivation, or a combination of both. Cognitive performance was measured using the Psychomotor Vigilance Task, with a self-reported measure of performance obtained before each cognitive battery. Overall, participants were able to predict their cognitive performance, however, there was a variety of factors involved in accuracy, including individual differences, and contributory factors fatigue such as environmental stressors, the length of shift, and the number of days worked. Subjective judgments appear to offer an effective, efficient, and cost effective tool in providing feedback in regard to in continuing work. In order for these to be effective however, subjective assessments should not be used in isolation, and fire-fighters must be trained, informed and given the tools to be able to recognise and monitor their own fatigue.

1. Introduction

The suppression of bushfires involves a coordinated effort by various emergency services personnel, including around 220,000 volunteer rural fire-fighters scattered across rural and remote Australia (McLennan and Birch, 2005). Severe bushfires often require multiple day deployments to remote areas, whereby fire-fighters work consecutive day or night shifts, ranging from 12 to 18 h, sometimes following a full or partial day of usual employment. Fire-fighting work has been likened to military battlefield environments that are characterised by intense physical work in extreme and stressful conditions (Aisbett et al., 2012; Lieberman et al., 2005). Added to this, minimal opportunities exist between shifts for sleep and recovery in conditions that can be less than ideal, which can lead to partial or total sleep deprivation (Jay et al., 2015; Miller et al., 2011). Ideally, crews are regularly rotated and tasks allocated according to fatigue levels. However where there is a lack of replacement crews, and/or the fire is burning out of control and needs urgent attention, crew or task rotation is not always possible (Aisbett and Nichols, 2007).

The work that fire-fighters undertake requires a high level of vigilance (e.g., walking through rocky terrain, operating machinery or driving, responding to instruction) (Aisbett and Nichols, 2007; Mangan, 1999), as well as the ability to make sound judgements in response to their surrounding environments (Lee, 2011). Bushfire suppression presents multiple occupational and environmental stressors such as inadequate sleep, long periods of wakefulness, use of personal protective equipment, intense physical work and extreme environmental conditions, all of which may make fire-fighters vulnerable to mental and physical fatigue, and increase the likelihood of fatigue related injuries (Aisbett and Nichols, 2007; Lee, 2011). Managing the risk of fatigue-related incidents and accidents is done through tailored fatigue risk management systems (Lerman et al., 2012).

Fatigue risk management systems generally include strategies that allow and support individuals on the 'frontline' to take control of, and manage, their own fatigue. In some settings, such assessments are facilitated by symptom checklists and self-report behavioural scales. Assessment can also take the form of self-rating of performance (Dorrian et al., 2000). The New South Wales Rural Fire Service for example, have adapted a model designed by

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Dawson and McCulloch (2005), that places responsibility on their members to report and refrain from working if they believe they are fatigued. Prior to commencement of duty and at any point during their shift, they are required to inform supervisors if they believe they are unfit for duty. In order for such controls to be effective however, fire-fighters must be trained, informed and given the tools to be able to recognise and monitor their own fatigue.

Subjective measures of fatigue and self monitoring cognitive performance have been shown in controlled laboratory conditions to change when individuals are sleep deprived (Odle-Dusseau et al., 2010; Dorrian et al., 2000; Babkoff et al., 1991; Belenky et al., 2003; Ferguson et al., 2012), or impaired by other factors (Balgrove and Akehurst, 2000; Baranski and Pigeau, 1997; Boksem et al., 2006; Fairclough and Graham, 1999). In general, and to a point, participants experiencing sleep deprivation are able to recognise increasing levels of fatigue, decreasing alertness, and changes in their cognitive performance (Dorrian et al., 2000, 2003; Gillberg et al., 1994; Macdonald and Bendak, 2000). Such assessments are vital as they may provide early indication of increasing fatigue-related risk (Odle-Dusseau et al., 2010), and thus a practical trigger for implementing controls. However, the use of subjective measures for monitoring fatigue and cognitive performance has largely been restricted to laboratory-based methodologies that do not reflect the multi-stressor environments to which rural fire-fighters are exposed (namely long periods of intermittent physical work, heat, sleep deprivation). In addition, the age demographics and physical fitness levels of the populations in many laboratory studies do not reflect the age and fitness level of actual rural fire-fighters. The innovative use of an end-user designed, simulated fireground deployment, allowed us to accurately represent the multi-stressor environment faced by rural fire-fighters. The aim of this study was to investigate the degree to which active rural fire-fighters could accurately self-monitor their performance throughout a simulated fire-ground tour.

2. Materials and methods

2.1. Participants

A total of 91 healthy volunteer rural fire-fighters (Males, $N = 79$, Females; $N = 12$) were recruited to take part in the study. The participants had an overall mean (±SD) age of 38.42, (±14.42), and an average body mass index (BMI) of 27.8 kg/m^2 (±4.53). This appears representative of current populations of active Australian rural fire-fighters (McLennan and Birch, 2005). Participants were recruited from various state and territory rural fire agencies Australia wide (SA, ACT, NSW, TAS) through emails and advertisements placed in member magazines/newsletters. Participants were required to be within the ages of 18–70 years old. Before participation, fire-fighters were screened, and excluded if they: had a current or pre-existing injury or condition that prevented them carrying out fire ground duties; were diagnosed with a sleep disorder; or were pregnant. Participants were assigned to either the 'control', 'awake', 'hot', or a combination of 'awake and hot' condition (see Table 1). Participants self selected suitable dates for testing, but were not aware of what condition they would be in. A total of 21 study trials were conducted at three locations (Adelaide $n = 11$, Melbourne $n = 7$, Canberra $n = 3$). The number of participants in any particular study trial ranged from 2 to 5.

2.2. Procedure

We designed an innovative simulation of a 3-day fire-ground tour (12 h work shifts over three consecutive days) that involved real-world physical tasks performed routinely by Australian tanker based fire-fighters under conditions of elevated ambient temperature and moderate sleep restriction. All components of the simulation, including day and night temperatures, sleeping environment, as well as physical and cognitive test batteries were designed in conjunction with subject matter experts and using field data (Ferguson et al., 2011).

The study protocol spanned four days to account for a study briefing, familiarisation of the tasks, and adaption to sleeping conditions (stretcher bed) on the evening prior to testing, as well as a morning testing session on day four. Participants lived in a simulated environment for the duration of the study (including physical tasks, rest breaks, meals, and sleeping) and were asked to remain inside excluding when smoking or using amenities that were located outside. During the daytime, participants adhered to a strict schedule, completing 15 2-h testing sessions over 4 days (Fig. 1). Each session consisted of 55 min of physical work designed to replicate fire-ground tasks, followed by physiological testing lasting 20 min (i.e., cortisol, glucose, blood, lung function, and grip strength. Core body temperature, heart rate, and urine output were also recorded), and a cognitive battery lasting 20 min (i.e., Go/No Go, Stroop, PVT, Memory, Occupational Safety Performance Assessment Technology). Testing sessions were completed in full protective clothing including wearing helmets and gloves. On completion of each session participants had a 15–30 min break before beginning the next session. After dinner participants were allocated free time until bedtime (e.g., read books, play board games or watch movies).

Table 1
Overview of the each study condition, locations, and participant demographics.

	Control	Hot	Awake	Awake + Hot
Experimental conditions				
Physical activity	14 circuits	14 circuits	14 circuits	14 circuits
Temperature				
Day (6 am–6 pm)	18–20 degrees	33–35 degrees	18–20 degrees	33–35 degrees
Night (6 pm–6 am)	18–20 degrees	23–25 degrees	18–20 degrees	23–25 degrees
Sleep opportunity				
Adaption/Recovery (nights 1 and 4)	8 h	8 h	8 h	8 h
Experimental (nights 2 and 3)	8 h	8 h	4 h	4 h
Demographics				
Fire-fighters tested ($n = 91$)	31	21	25	14
Withdrawals ($n = 7$)	1	3	2	1
Males ($n = 79$)	28	17	21	13
Females ($n = 12$)	3	4	4	1
Age in years ($M = 38.42 \pm 14.42$)	38.90 (15.45)	34.76 (13.02)	39.00 (13.59)	41.79 (16.38)
Body mass index ($M = 27.8 \pm 4.53$)	27.29 (4.83)	27.42 (4.10)	29.44 (4.9)	26.78 (4.18)