Deakin Research Online

This is the published version:

Phillips, Matthew, Netto, Kevin, Payne, Warren, Nichols, David, Lord, Cara, Brooksbank, Neil, Onus, Katrina, Jefferies, Sarah and Aisbett, Brad 2011, Frequency, intensity and duration of physical tasks performed by Australian rural firefighters during bushfire suppression, *in Proceedings of Bushfire CRC & AFAC 2011 Conference Science Day*, Bushfire Cooperative Research Centre, East Melbourne, Vic., pp. 205-213.

Available from Deakin Research Online:

http://hdl.handle.net/10536/DRO/DU:30043862

Reproduced with the kind permission of the copyright owner.

Copyright: 2011, Bushfire Cooperative Research Centre.

Frequency, intensity and duration of physical tasks performed by Australian rural firefighters during bushfire suppression

Matthew Phillips[1,2], Kevin Netto[1], Warren Payne[3], David Nichols[2,4], Cara Lord[1,2], Neil Brooksbank[5], Katrina Onus[1,2], Sarah Jefferies[1] and Brad Aisbett[1,2].*

[1] Centre for Exercise and Sports Sciences, School of Exercise and Nutrition Sciences, Deakin University, Burwood, Vic

[2]Bushfire Co-Operative Research Centre, East Melbourne, Vic

[3]Office for Research, Victoria University, Footscray, Vic

[4]Country Fire Authority, Burwood East, Vic

[5]Tasmania Fire Service, Tasmania, Australia

** Corresponding Author: brad.aisbett@deakin.edu.au*

Additional Keywords: job task analyses, wildfire

ABSTRACT

The current study combined, for the first time, video footage of individual firefighters wearing heart rate monitors and personal GPS units to quantify the frequency, duration and intensity of tasks performed by Australian rural fire crews when suppressing bushfires. Across the four fireground 'shifts', the firefighters performed 34 distinct fireground tasks. Per shift, the task frequency ranged from once (raking fireline in teams, carrying a quick fill pump) to 103 times (lateral repositioning of a 38-mm charged firehose). The tasks lasted between 4 ± 2 s (bowling out 38-mm firehose) and 461 ± 387 s (raking fireline in teams). The task intensity, as measured by average heart rate ranged between 97 ± 16 beats·min^{-1} (55.7 ± 8.7 %HR_{max}) and 157 ± 15 beats·min^{-1} (86.2 ± 10.8 %HR_{max}). The tasks were performed a speeds that ranged from 0.12 ± 0.08 m·s^{-1} (manual hose retraction of 38-mm charged firehose) to 0.79 ± 0.40 m·s^{-1} (carrying a 38-mm coiled hose). Tasks found to be simultaneously frequent, long and intense (or two of these three) are likely to form the basis for job-specific testing of Australian rural firefighters suppressing bushfires.

Introduction

Several approaches have been utilised to capture firefighter's task demands including; subjective job task analyses (Gledhill and Jamnik 1992b; Phillips *et al. in press*), physiological and biomechanical analysis of isolated tasks (Gledhill and Jamnik 1992a; Brotherhood *et al.* 1997; Bilzon *et al.* 2001; Gregory *et al.* 2008), time and motion analysis of simulated bushfire suppression (Budd *et al.* 1997b) and urban emergency (Bos *et al.* 2004),and remote monitoring of heart rate or energy expenditure during emergency fire shifts in the United States of America (US) (Ruby *et al.* 2002; Ruby *et al.* 2003; Cuddy *et al.* 2007) and Spain (Rodríguez-Marroyo *et al.* 2011). Limitations of these approaches include; the highly variable recall of task frequency and duration by subject matter experts (SMEs; Morgeson and Campion 1997; Lindell *et al.* 1998), work intensity measures during isolated task simulations that do not provide insight into the frequency with which a task occurs, or the duration of successive task repetitions on shift and lastly, whole shift measures of energy expenditure (Heil 2002) or heart rate (Rodríguez-Marroyo *et al.* 2011) that are unable to isolate task demands specifically.

Three studies have used direct observation to characterise the inherent requirements of physically demanding occupational work. Budd et al (Budd *et al.* 1997b) recorded the frequency and duration of Australian land management crew firefighting activities via direct observation but did not record real time physiological measurements to quantify task 'demands'. Bos et al (Bos *et al.* 2004) utilised video analysis and wireless heart rate monitoring to quantify the frequency and duration of physical demands on urban Dutch firefighters during a 24-hour shift. They reported that urban firefighting could be characterised by a low frequency of incidents which are short in duration with a moderate to occasionally high workload. However, they relied only on heart rate alone which typically has a delayed reaction to activity changes, resulting in either residually lower or higher heart rate for subsequent tasks. Lastly, Wyss and Mader (2011) recently advocated the use of video analysis to verify task analysis of physically demanding Swiss military tasks along with personal monitoring (e.g., HR, physical activity).

To date, our group has undertaken subjective job task analyses (Phillips *et al. in press*), quantified oxygen uptake and heart rate during simulations of isolated tasks (Phillips *et al.* 2008) and measured heart rate and activity across multiple shifts (Raines *et al. in press*) but neither our group or others has quantified the frequency, intensity, duration and type of tasks firefighters perform on the fireground. Therefore the aim of this study was to use video footage of individual firefighters wearing heart rate and GPS monitors to characterise these parameters during a bushfire suppression shift. Particular attention was focussed on tasks that were simultaneously frequent, intense and / or long-lasting. Such tasks were identified as 'critical'; modifying the previous 'cumulative stress' paradigm used in job task analyses of Australian Naval clearance divers (Taylor and Groeller 2003).

Methods

Twenty eight operationally active volunteer firefighters (22 males and six females) from local brigades of the Tasmanian Fire Service (TFS) participated in one of four single-day bushfires in dry eucalypt forest of North Eastern and South Western Tasmania during September – October, 2008. Across the four days, the temperatures ranged 18 to 24°C with 0.6 to 3.2 mm of rainfall and light winds. The fires were lit as part of large scale prescribed burning operations, facilitating the current research, similar to earlier work with Australian land management firefighters (Budd *et al.* 1997a).

Recruitment to the study occurred at pre-shift briefings before deployment to their normal work shift. All participants were fitted with a portable 1-Hz GPS monitor (WiSPI, GPSports, Australia), worn in the manufacturer's harness mounted between the shoulder blades. Heart rate data was received through the GPS device from a chest strap. Firefighters also wore full protective gear (approx. 5kg in weight) as per standard operating procedures. Throughout the shift each firefighter was followed by a researcher and a fire-service provided safety advisor. The researcher used a handheld digital video camera to capture footage of their firefighter's work tasks and movements although they did not film during rest periods or during vehicle transit.

Data analysis

At the conclusion of each shift, logged GPS coordinates were downloaded from the devices and converted into distance and velocity information using Team AMS software (GPSports, Australia). Heart rate and velocity data were downloaded at one-second epochs and digital video was captured by Dartfish TeamPro® (Fribourg, Switzerland) and the types of tasks analysed were identified using a custom made rural firefighting specific tagging profile drawing on our previous job task analysis (Phillips *et al. in press*). The tagging profile was used to quantify the frequency and duration for each discrete task performed by the firefighters. The footage was then time-synchronised to within one epoch with heart rate and velocity data to isolate the intensity (heart rate and velocity of each task). This was performed using the functionality of the Dartfish software which allows input of other measures. Task velocity is expressed in $m \cdot s^{-1}$ and heart rate in both absolute units (beats$\cdot$min^{-1}) and relative to age-predicted maximum (%HRmax) using the predictive formula: *HRmax = 207 – (0.7 x age*; Gellish *et al.* 2007).

Statistical analysis

All tasks (34 in total) were ranked in terms of frequency, intensity and time and the top three for each list are presented in the results section. Thereafter, tasks that appear in the top ten on two or more of these lists were presented to physical tasks that were simultaneously frequent, intense, and/or long lasting in an effort to identify critical fireground duties.

Results

Across the four 'shifts', 34 distinct fireground tasks were performed. Of these, nineteen tasks were classified as hose work, five as handtool (primarily rakehoe) and the remaining eight were classed as miscellaneous.

Frequency

The three most frequent tasks were performed between 66 and 103 times across a six-hour fireground shift and were; laterally repositioning a 38-mm diameter charged (i.e., filled with pressurized liquid) fire hose (103 repetitions), purposeful or 'targeted' walks (95), and supporting a colleague using a 38-mm diameter charged fire hose (66).

Intensity

Intensity was measured as the highest relative heart rate (% of age-predicted heart rate maximum) and ranged from 82.1 ± 12.9 $\%HR_{max}$ to 86.2 ± 10.8 $\%HR_{max}$. The three most intense firefighting tasks were; building firebreaks using handtools, in teams (86.2 ± 10.8% $\%HR_{max}$), carrying a tightly coiled 38-mm diameter fire hose (83.4 ± 13.7 $\%HR_{max}$) and tightly coiling a 38-mm diameter firehose (82.1 ± 12.9 $\%HR_{max}$).

Speed

The speed of movement during the three fastest firefighting tasks ranged from 0.76 ± 0.51$m{\cdot}s^{-1}$ to 0.79 ± 0.40 $m{\cdot}s^{-1}$. These tasks included; carrying a tightly coiled 38-mm fire hose (0.79 ± 0.40 $m{\cdot}s^{-1}$), supporting crew on the fireline (0.78 ± 0.71 $m{\cdot}s^{-1}$) and purposeful or 'targeted' walks (0.76 ± 0.51$m{\cdot}s^{-1}$). This category of tasks was excluded from the composite list of tasks (Table 1) so as not to bias the scaling towards two measures of intensity (ie. , mean HR and speed)

Duration

The three longest tasks ranged from 119 ± 112 s to 461 ± 387 s. These tasks (time in seconds) included building firebreaks using handtools, in teams (461 ± 387 s), using a 25-mm diameter charged firehose to douse burnt debris during post-fire cleanup work (130 ± 138 s) and extracting water from a water point (i.e., lake, dam; 119 ± 112 s).

Frequency, Intensity, Duration

A composite list of five tasks that were ranked in the top ten for two or more of frequency, intensity and duration is presented (along with frequency, intensity and duration data) in Table 1. These tasks (with the lists on which they featured on the top ten in brackets) included using a 38-mm diameter charged firehose during post fire clean up (duration, frequency and intensity), building firebreaks using handtools, in teams (duration and intensity), laterally repositioning a 38-mm diameter charged firehose (duration and frequency), operating a 38-mm diameter charged fire hose (duration and frequency) and tightly coiling a 38-mm diameter firehose (duration and intensity).

Discussion

This is the first study that has quantified the frequency and duration with which firefighting tasks are performed during a bushfire suppression shift. As such, comparisons are limited to previous work using SMEs (Phillips *et al. in press*) and other firefighting jurisdictions, including urban, naval and forestry firefighting.

The most frequent tasks were performed between 29 (mount/dismount fire tanker) and 103 (lateral reposition of a 38-mm charged fire hose) times across a six-hour fireground shift. In a previous study (Phillips *et al. in press*), task frequency was estimated per four-month Australian bushfire season making it difficult to precisely compare to the 'per shift' observations in the current study. However, when relative 'rankings' are compared, both SMEs and our current observations places lateral repositioning a 38-mm diameter charged firehose as the most frequent task, followed by full repositioning of a 38-mm diameter charged firehose and hand tool work during post fire clean up duties. Solo and team based hand tool work were amongst the least frequent tasks in both studies (Phillips *et al. in press*).

Heart rates obtained in the current study were lower than those recorded in simulations of Australian bushfire suppression (Phillips *et al.* 2008), Canadian urban (Gledhill and Jamnik 1992a), British naval (Bilzon *et al.* 2001) and Australian land management crew (Brotherhood *et al.* 1997) firefighting tasks. Possible explanations for this include shorter task durations, slower task speeds and in some cases, lighter equipment. Nevertheless, the most intense tasks in this study could be classified as moderate to hard (vigorous) work by the ACSM (ACSM 2010). Vigorous work can precipitate adverse cardiac events in individuals with underlying cardiovascular disease (ACSM 2010). To reduce the risk of adverse cardiac events during vigorous exercise, health and fitness settings usually require that participants undergo some form of medical screening prior to starting an exercise regimen. In volunteer firefighting, this type of screening is not mandatory, potentially putting volunteers at risk if they are working in the vigorous heart rate zone (ACSM 2010).

The longest tasks observed on the fireground ranged 54 s to 7.6 min. The duration of these tasks was generally shorter than those simulated for Canadian urban (Gledhill and Jamnik 1992a), US forestry (Sharkey 1999), Australian land management (Ellis and Gilbert 1997) and Australian rural fire authority (Phillips *et al.* 2008) firefighting. The comparative differences between these previous studies and the current work could arise from genuine differences in task length between firefighting types and jurisdictions. Furthermore, single-repetition simulations are often designed to elicit steady-state cardiovascular responses and, as such, are much longer than self-paced work durations performed across a shift (Brotherhood *et al.* 1997).

In urban and land management firefighters (AFAC 2002), recruit, seasonal and sometimes incumbent personnel are required to pass physical employment standards before deployment on the fireground. In Australia, rural authority firefighters do not have a purpose-built physical selection test (Lord *et al.in press*). In order to be able to identify the representative tasks that could feature in such a test, the current study identified tasks that ranked in the top ten for two or more of frequency, intensity and duration (Table 1). This attempt to isolate 'critical' tasks is similar to the 'cumulative stress' paradigm used by Taylor and Groeller (2003) which ranked tasks based on the product of difficulty and frequency. Tasks found to be simultaneously frequent, long and intense (or two of these three) included using a 38-mm diameter charged firehose during post fire cleanup, building firebreaks using handtools in teams, laterally repositioning a 38-mm diameter charged firehose, operating a 38-mm diameter charged fire hose and tightly coiling a 38-mm diameter firehose (Table 1).

The current results are based on four whole-day shifts in one Australian state. The data collected, though comprehensive, may need to be supplemented by input from other regions. The collection of frequency, intensity and duration data during actual firefighting using video analyses is, however, time consuming, expensive and requires dedicated agency support. For agencies and researchers seeking to apply these current findings to other Australian regions, a more time and cost effective approach may be to use workshops where video footage and physiological data can be interrogated by multiple stakeholders so that inter-region variations in work practices can be captured, discussed and resolved.

The current study combined, for the first time, video footage of individual firefighters wearing heart rate monitors and personal GPS units to quantify the frequency, intensity, duration and type of tasks performed by Australian rural fire crews when suppressing bushfires. Task frequency has not yet been quantified in previous emergency service literature. Fireground tasks were, generally speaking, slower, performed at slower speeds and elicited lower heart rate responses than simulated tasks in Australian bushfire, Canadian and Dutch urban, British naval or US or Spanish forestry contexts. Five hose tasks and one raking task were found to be simultaneously frequent, intense and long-lasting (or two of these) and should be considered when designing a work-specific simulation or physical selection test for Australian rural firefighters suppressing bushfires.

References

ACSM (2010) ACSM's Guidelines for Exercise Testing and Prescription. (Wolters Kluwer / Lippincott Williams & Wilkins: Philadelphia).

AFAC (2002) AFAC guidelines for health and fitness monitoring of Australiasian fire and emergency service workers. Australasian Fire Authorities Council, East Melbourne Australia, p. 95.

Bilzon J, Scarpello E, Smith C, Ravenhill N, Rayson M (2001) Characterization of the metabolic demands of simulated shipboard Royal Navy fire-fighting tasks. *Ergonomics* **44**, 776-780.

Bos J, Mol E, Visser B, Frings-Dresen M (2004) The physical demands upon (Dutch) fire-fighters in relation to the maximum acceptable energetic workload. *Ergonomics* **47**, 446-460.

Brotherhood J, Budd G, Hendrie A, Jeffrey S, Beasley F, Costin B, Zhien W, Baker M, Cheney N, Dawson M (1997) **Project Aquarius 3.** Effects of work rate on the productivity, energy expenditure, and physiological responses of men building fireline with a rakehoe in dry eucalypt forest. *International Journal of Wildland Fire* **7**, 87-98.

Budd G, Brotherhood J, Hendrie A, Jeffery S, Beasley F, Costin B, Zhien W, Baker M, Cheney N, Dawson M (1997a) **Project Aquarius 1.** Stress, Strain, and Productivity in Men Suppressing Australian Summer Bushfires With Hand Tools: Background, Objectives, and Methods. *International Journal of Wildland Fire* **7**, 69-76.

Budd G, Brotherhood J, Hendrie A, Jeffrey S, Beasley F, Costin B, Zhien W, Baker M, Cheney N, Dawson M (1997b) **Project Aquarius 5.** Activity distribution, energy expenditure, and productivity of men suppressing free-running wildland fires with hand tools. *International Journal of Wildland Fire* **7**, 105-118.

Cuddy JS, Gaskill SE, Sharkey BJ, Harger SG, Ruby BC (2007) Supplemental feedings increase self-selected work output during wildfire suppression. *Medicine and Science in Sports and Exercise* **39**, 1004-1012.

Ellis S, Gilbert L (1997) Job related taskbased assessments. AFAC Guidelines: National Approach to Physical Performance Assessment for Firefighters. Australasian Fire Authorities Council, East Melbourne, Australia, p. 9.

Gellish R, Gosliin B, Olson R, McDonald A, Russi G, Moudgil V (2007) Longitudinal Modeling of the Relationship between Age and Maximal Heart Rate. *Medicine and Science in Sports and Exercise* **39**, 822-829

Gledhill N, Jamnik VK (1992a) Characterization of the physical demands of firefighting. *Canadian Journal of Sports Sciences* **17**, 207-213.

Gledhill N, Jamnik VK (1992b) Development and validation of a fitness screening protocol for firefighter applicants. *Canadian Journal of Sports Sciences* **17**, 199-206.

Gregory D, Narula S, Howarth S, Russell C, Callaghan J (2008) The effect of fatigue on trunk muscle activation patterns and spine postures during simulated firefighting tasks. *Ergonomics* **51**, 1032 - 1041

Heil DP (2002) Estimating energy expenditure in wildland fire fighters using a physical activity monitor. *Applied Ergonomics* **33**, 405-413.

Lindell MK, Clause CS, Brandt CJ, Landis RL (1998) Relationship between organisational context and job analysis task ratings. *Journal of Applied Psychology* **83**, 769-776.

Lord C, Netto K, Petersen A, Nichols D, Drain J, Phillips M, Aisbett B (*In press*) Validating `fit for duty' tests for Australian volunteer fire fighters suppressing bushfires. *Applied Ergonomics.*

Morgeson FP, Campion MA (1997) Social and cognitive sources of potential inaccuracy in job analysis. *Journal of Applied Psychology* **82**, 627-655.

Phillips M, Payne W, Lord C, Netto K, Nichols D, Aisbett B (*in press*) Identification of physically demanding tasks performed during bushfire suppression by Australian rural firefighters. *Applied Ergonomics.*

Phillips M, Raines J, McConell G, Nichols D, Aisbett B (2008) The Aerobic Energy Demands Of Simulated Tanker- Based Wildfire Fighting Tasks. *Medicine and Science in Sports and Exercise* **40**, S354.

Raines J, Snow R, Petersen A, Harvey J, Nichols D, Aisbett B (*in press*) Pre-shift fluid intake: Effect on physiology, work and drinking during emergency wildfire fighting. *Applied Ergonomics.*

Rodríguez-Marroyo J, López-Satue J, Pernía R, Carballo B, García-López J, Foster C, Villa J (2011) Physiological work demands of Spanish wildland firefighters during wildfire suppression. *International Archives of Occupational and Environmental Health*, 1-8.

Ruby B, Schoeller D, Sharkey B, Burks C, Tysk S (2003) Water Turnover and Changes in Body Composition during Arduous Wildfire Suppression. Medicine and Science in Sports and Exercise 35, 1760-1765.

Ruby B, Schriver T, Zderic T, Sharkey B, Burks C, Tysk S (2002) Total energy expenditure during arduous wildfire suppression. Medicine and Science in Sports and Exercise 34, 1048-1054.

Sharkey B (1999) Development and validation of a job-related work capacity test for wildland firefighters. International Association of Wildland Fire, Sydney, Australia.

Taylor NA, Groeller H (2003) Work-based physiological assessment of physically-demanding trades: a methodological overview. Journal of Physiological Anthropology and Applied Human Science 22, 73-81.

Wyss T, Mäder U (2010) Recognition of military-specific physical activities with body-fixed sensors. Military Medicine **175,** 858-864.

Table 5 Tasks that were ranked in the top ten for two or more of frequency, intensity (mean relative heart rate), and duration during bushfire suppression

Task	Frequency	Average HR (beats.min^{-1}) (%HR max)	Peak HR (beats.min^{-1}) (%HR max)	Speed (m.s^{-1})	Duration (s)	Type (Hose, Rake, Misc)
38-mm hose blacking out work	41	126 ± 24 (71.9 ± 15.3)	131 ± 24 (75.0 ± 15.0)	0.26 ± 0.19	76 ± 70	Hose
38-mm hose lateral repositioning	103	127 ± 23 (71.5 ± 12.6)	130 ± 23 (73.2 ± 12.5)	0.40 ± 0.29	17 ± 14	Hose
38-mm hose operating	41	124 ± 19 (69.8 ± 10.6)	129 ± 20 (72.4 ± 10.8)	0.34 ± 0.37	40 ± 69	Hose
Tightly coiling a 38-mm hose	5	155 ± 24 (82.1 ± 12.9)	164 ± 25 (86.8 ± 13.2)	0.40 ± 0.26	62 ± 47	Hose
Team hand tool line building	1	157 ± 15 (86.2 ± 10.8)	168 ± 10 (92.2 ± 7.7)	0.14 ± 0.08	461 ± 387	Rake

All data are means ± SD, HR; heart rate, min; minutes, % HRmax; percentage of age-predicted heart rate maximum [19], m.s^{-1}; metres per second, SD; standard deviation, Misc; miscellaneous task, mm; millimetres