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Abstract

Objective: To quantify the frequency, intensity, duration, and type of tasks performed by Australian rural fire crews when suppressing wildfires.

Methods: Twenty-eight Australian rural firefighters worked across four, six-hour shifts fighting to curtail the spread of wildfire. Each firefighter wore a heart rate monitor and personal global positioning system (GPS) unit and was followed by a researcher filming their work activity. Video footage of each firefighter was synchronized with their heart rate and GPS data to quantify the frequency, intensity and duration of individual fireground tasks. Fireground tasks were isolated using a previously conducted job task analysis.

Results: Firefighters performed 32 distinct fireground tasks. Task frequencies ranged from once to 103 times per six-hour shift. Individual tasks lasted 4 ± 2 s to 461 ± 387 s, were performed at speeds ranging from 0.12 ± 0.08 $m \cdot s^{-1}$ to 0.79 ± 0.40 $m \cdot s^{-1}$ and elicited mean heart rates that ranged between 97 ± 16 $beats \cdot min^{-1}$ (55.7 ± 8.7 percentage of age-predicted maximum heart rate (HRmax)) and 157 ± 15 $beats \cdot min^{-1}$ (86.2 ± 10.8%HRmax).

Conclusion: Fireground tasks were, generally speaking, shorter, slower, and elicited lower heart rates than equivalent tasks previously simulated and reported in the literature. The differences between naturally occurring and simulated tasks question the value of isolated task simulations for conducting physical demands analyses en-route to developing job-specific fitness tests.wffo
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et al. [8] reported that urban firefighting can be characterised by a low frequency of incidents which were reported as short tasks with a moderate to occasionally high workload. As identified recently by Wyss and Mader [22] the benchmark study of Bos et al. [20] also have limitations. Firstly, heart rate has a delayed reaction to activity changes, a time lag which may translate into a lower than expected heart rate for an initial task in a sequence, or an inflated heart rate for subsequent tasks [22].Secondly, firefighters heart rate on shift is likely to reflect the combination of the psychological and physiological demands of their job [23].Thirdly, reliance on TRAC without subsequent verification of activity recordings with video may reduce the precision of the activity classifications [22]. Indeed, the validity of direct observations, including TRAC has been questioned for dynamic

		(61.8 ±12.4)	(62.8 ± 12.2)			

Table 1: Ten most frequent tasks performed per shift during wildfire suppression. All data are means ± SD, HR: Heart Rate; min: Minutes; %HRmax: Percentage of Age-predicted Heart Rate Maximum (14); $m \cdot s^{-1}$: Metres per Second; SD; Standard Deviation; Misc: Miscellaneous Task; mm: Millimetres.

The ten tasks with the highest mean relative heart rate (i.e., %HRmax) are presented in Table 2. The mean heart rates ranged from 69.4 ± 15.1%HRmax (raking during blacking out) to 86.2 ± 10.8%HRmax (raking fireline in teams). Eight tasks were classified as hose work, whilst the remaining two were considered handtool tasks.

The ten fastest tasks are presented in Table 3. The mean speed ranged from 0.40 ± 0.26 $m \cdot s^{-1}$ (tightly coiling a 38-mm fire hose) to 0.79 ± 0.40 $m \cdot s^{-1}$ (carrying a 38-mm coiled hose). Eight tasks were classified as hose work, whilst the remaining two were considered miscellaneous tasks.

Task	**Frequency**	**Mean HR ($beats \cdot min^{-1}$) (%HR max)**	**Peak HR ($beats \cdot min^{-1}$) (%HR max)**	**Speed ($m \cdot s^{-1}$)**	**Duration (s)**	**Type (Hose, Rake, Misc)**
Team line building	1	157 ± 15 (86.2 ± 10.8)	168 ± 10 (92.2 ± 7.7)	0.14 ± 0.08	461 ± 387	Rake
Carry coiled 38-mm hose	6	156 ± 29 (83.4 ± 13.7)	161 ± 28 (86.0 ± 13.4)	0.79 ± 0.40	49 ± 60	Hose
Making up 38-mm hose on bite	5	155 ± 24 (82.1 ± 12.9)	164 ± 25 (86.8 ± 13.2)	0.40 ± 0.26	62 ± 47	Hose
Manual 38-mm hose retraction	3	141 ± 29 (78.5 ± 16)	145 ± 29 (80.7 ± 15.6)	0.12 ± 0.08	45 ± 35	Hose
Advance uncharged 38-mm hose	3	133 ± 16 (72.3 ± 6.6)	137 ± 17 (74.5 ± 6.8)	0.46 ± 0.27	21 ± 12	Hose
Blacking out work using 38-mm hose	41	126 ± 24 (71.9 ± 15.3)	131 ± 24 (75.0 ± 15.0)	0.26 ± 0.19	76 ± 70	Hose
Lateral repositioning 38-mm hose	103	127 ± 23 (71.5 ± 12.6)	130 ± 23 (73.2 ± 15.5)	0.40 ± 0.29	17 ± 14	Hose
Operating 38-mm hose	41	124 ± 19 (69.8 ± 10.6)	129 ± 20 (72.4 ± 10.8)	0.34 ± 0.37	40 ± 58	Hose
‘Bowling’ out 38-mm hose	2	130 ± 36 (69.8 ± 18.8)	130 ± 36 (70.2 ± 18.7)	0.53 ± 0.54	4 ± 2	Hose
Rake hoe during blacking out	24	130 ± 29 (69.4 ± 15.1)	134 ± 31 (71.6 ± 15.9)	0.22 ± 0.11	25 ± 25	Rake

Support crew on fireline	5	101 ± 18 (55.0 ± 9.9)	112 ± 21 (60.8 ± 11.6)	0.78 ± 0.71	79 ± 51	Rake
Targeted walk	95	117 ± 25 (64.8 ± 12.7)	121 ± 25 (66.9 ± 12.8)	0.76 ± 0.51	23 ± 29	Misc
Move uncharged 38-mm hose onto fire break	3	120 ± 15 (65.9 ± 8.7)	126 ± 16 (69.2 ± 8.7)	0.57 ± 0.43	20 ± 15	Hose
Advance 38-mm charged hose	14	115 ± 23 (66.7 ± 13.4)	118 ± 23 (68.3 ± 13.3)	0.54 ± 0.48	17 ± 11	Hose
Full repositioning of 25-mm hose	7	106 ± 19 (59.1 ± 10.3)	115 ± 19 (64.0 ± 9.7)	0.54 ± 0.28	78 ± 42	Hose
‘Bowling’ out 38-mm hose	2	130 ± 36 (69.8 ± 18.8)	130 ± 36 (70.2 ± 18.7)	0.53 ± 0.54	4 ± 2	Hose
Advance 25-mm charged hose	14	104 ± 19 (59.5 ± 10.2)	109 ± 19 (61.8 ± 9.6)	0.49 ± 0.30	18 ± 10	Hose
Advance uncharged 38-mm hose	3	133 ± 16 (72.3 ± 6.6)	137 ± 17 (74.5 ± 6.8)	0.46 ± 0.27	21 ± 12	Hose

Quickfill pump set up	5	107 ± 13 (58.5 ± 8.0)	115 ± 13 (62.3 ± 8.2)	0.24 ± 0.13	70 ± 73	Misc
Making up 38-mm hose on bite	5	155 ± 24 (82.1 ± 12.9)	164 ± 25 (86.8 ± 13.2)	0.40 ± 0.26	62 ± 47	Hose
Manual 25-mm hose retraction	7	126 ± 27 (68.3 ± 14.5)	133 ± 28 (72.0 ± 15.0)	0.15 ± 0.13	54 ± 67	Hose

of tasks as most frequent across a 24-hour shift, but did not report the number of repetitions performed for each task. Of the «most frequent» activities (i.e., actions within global tasks) listed by Bos et al. [8] pulling and dragging hoses parallels the lateral repositioning of 38-mm and 25-mm charged fire hoses (Table 1) identified as the first and fourth most frequent wildfire suppression tasks (Table 1). In the current study also reported that operating a 38-mm charged fire hose (to deliver water or other suppressant), and supporting firefighters to perform this task (or operate a 25-mm firehose) were amongst the most frequent tasks (Table 1). These tasks could correspond (or at least contribute) to the «extinguishing» task set identified as «most frequent» by Bos et al. [8]. Possible task similarities between Dutch urban and Australian rural firefighters lends weight to our earlier conclusions regarding the overlap in work practices between structural firefighting worldwide and wildfire suppression by Australian rural firefighters [2].

The peak and mean heart rates (relative to age-predicted maximum) reported in the current study were, generally speaking, lower than those recorded in simulations of wildfire [26], urban [5], naval [3], and forestry [28] firefighting tasks. The lower heart rates observed in the current study can be explained, at least in part, by the shorter task durations and slower task speeds observed, and in some cases, lighter equipment used in the current study compared to previous research [3-5,31,32]. Differences between observed and simulated work rates are not limited to our work. For example, Bos et al. [8] showed that the mean heart rate per urban firefighting task was much lower during a 24-hour shift than had been reported during simulations of urban firefighting tasks [5]. The higher heart rates observed in simulation may be related to either the longer task duration, which could be a function of researchers seeking to establish steady-state cardiovascular responses to a particular task [3]. Alternatively, participants, despite instructions to perform simulated tasks «as they would on the job», may work at a higher speed than they do in the field [9]. This observation may reflect a form of «reactivity» where participants increase their physical activity when they know they are being monitored or can view their pedometer [32]. It is also possible that emergency service workers lower their task speed and therefore heart rate to pace their efforts across a whole shift. This hypothesis, though raised previously by Budd and colleagues [9] is yet to be directly tested, though recent observations of Spanish wildland firefighters [33] do show a lowering of mean heart rate with longer shifts. Future simulations of emergency services tasks and work may, accordingly, require multiple task repetitions to adequately represent the work demands faced «on the job».

The task durations observed in the current study are also considerably shorter than those proposed by experienced Australian rural firefighters during a subjective job task analysis on wildfire suppression [2]. The comparison, notwithstanding small differences in tasks between ur_ ⊩ latas ᵠɹMᶠMcome-prduraatas nᴰl

observed fireground tasks were, generally speaking, slower, performed at lower speeds, and elicited lower heart rate responses than simulated tasks in wildfire, structural, naval, or forestry contexts. The tasks were also shorter than previous subjective job task analysis findings, supporting a recent review [18] in this area. The current results, albeit drawing upon a modest sample, indicate that single repetition task simulations may not accurately capture work demands. These results, if replicated across other jurisdictions could significantly alter the process used to design job-specific fitness testing and training regimes. From the 32 tasks observed, only five tasks were found to be simultaneously frequent, long and intense (or ranked in the top 10 tasks for two of these three indices). They were team line building, lateral repositioning of a 38-mm firehose, using a 38-mm firehose during blacking out, operating a 38-mm firehose, and tightly coiling a 38-mm fire hose. These tasks are likely to form the basis for any future

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