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BRIEF REPORT

Work Patterns Dictate Energy Demands and Thermal Strain During Wildland Firefighting

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Objective.—The purpose of this investigation was to characterize the effects of self-selected work activity on energy expenditure, water turnover, and thermal strain during wildland fire suppression. A secondary aim was to contrast current data with data collected 15 years ago using similar methods to determine whether job demands have changed.

Methods.—Participants (n = 15, 26 ± 3 years, 179 ± 6 cm, 78.3 ± 8.6 kg) were monitored for 3 days for total energy expenditure, water turnover, core and chest skin temperature, physical activity, and heart rate. Participants arrived to the mobile laboratory each morning, submitted a nude weight, ingested a temperature transmitter, provided a urine sample, and were equipped with a physiological and activity monitor. Participants completed live wildland fire suppression during their work shifts.

Results.—Mean core temperature was 37.6° ± 0.2°C, mean chest skin temperature was 34.1° ± 1.0°C, mean heart rate was 112 ± 13 beats/min, and the mean physiological strain index score was 3.3 ± 1.0. Wildland firefighters spent 49 ± 8%, 39 ± 6%, and 12 ± 2% in the sedentary, light, and moderate-vigorous intensity categories, respectively. The mean total energy expenditure was 19.1 ± 3.9 MJ/d, similar to 1997 (17.5 ± 6.9 MJ/d). The mean water turnover in 2012 was 9.5 ± 1.7 L/d, which was higher ($P < .05$) compared with 1997–98 (7.0 ± 1.7 L/d).

Conclusions.—Wildland firefighters do not induce consistently high cardiovascular and thermal strain while completing arduous work in a hot environment despite fairly high chest skin temperatures. The total energy expenditure in the current study suggests job demands are similar to those of 15 years ago, while the increased water turnover may reflect a change in drinking habits.

Key words: skin temperature, core temperature, occupational physiology, field study

Introduction

Wildland firefighters (WLFFs) are subjected to a multitude of environmental and physical demands on a day-to-day basis. High energy (17.5 ± 6.9 MJ/d) and fluid demands (6.7 ± 1.4 L/d) result from 12 to 16 hours of physical labor (229 ± 56 kcal/h for 16 hours) in hot environments in an effort to control wildland fires.[1,2] Thermoregulation for the WLFF is challenged by high ambient and radiant temperatures, as well as wearing required personal protective equipment. When combined with high metabolic demand, this can lead to heat-related injuries, and even fatalities, as a result of rigorous occupational tasks and exposure to the elements.[3,4] Firefighters self-regulate body temperature in response to different ambient conditions by altering work and rest cycles and work intensity.[5] Objective measures of work effort, along with measures of thermal strain, have not been directly observed alongside the measures of total energy expenditure (TEE) and water turnover (rH_2O) during wildfire suppression. The purpose of this investigation is to characterize the effects of self-selected work activity on TEE, rH_2O, and thermal strain during wildland fire suppression. A secondary aim was to contrast the current data with data collected 15 years ago to determine whether the job demands have changed.

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Methods

EXPERIMENTAL DESIGN

Twelve male and 3 female participants (n = 15, 26 ± 3 years, 179 ± 6 cm, 78.3 ± 8.6 kg, body mass index 24.3 ± 1.7 kg/m^2) were recruited from two Type I Interagency Hot Shot fire crews and monitored for 3 days. Participants provided informed consent by signing a university-approved institutional review board consent form. The evening (approximately 10 PM) before beginning their work shift, participants were weighed in the nude using a calibrated digital scale (Ohaus CW-11, Ohaus Corp, Pinebrook, NJ), verbally provided their height, and were given an oral dose of tracer water, $^2H_2^{18}O$ (100 g; 1.82 g ^{18}O per kg body mass, 0.13 g $^2H_2$ per kg body mass). Each day participants arrived to the mobile laboratory in the early morning, provided body mass, ingested a disposable temperature transmitter pill (Jonah capsule, Vitalsense, Mini Mitter, Bend, OR), provided a urine sample, and were equipped with the Hidalgo Equivital EQO2 LifeMonitor system (Hidalgo Limited, Cambridge, UK) which collected heart rate (HR) and received transmission from the core pill, and an ActiCal activity monitor (Mini Mitter). The isotopic enrichments of urines collected on each morning and evening were used to determine elimination rates, water turnover, and carbon dioxide production. For a more detailed report of these procedures, see Ruby et al[1,2] and Cuddy et al.[6] Intensity of activity was determined by activity count cut points (≤99, 100–1499, and ≥1500 for sedentary, light, and moderate/vigorous, respectively) as has been previously reported during similar work.[7] After being equipped, participants went to work doing live wildfire suppression (High Park Fire, Fort Collins, CO, which burned 353.23 km^2, or 87,284 acres), which involved activities such as hiking, line digging, laying hose, chain sawing, clearing brush, lookout, and scouting. Work shifts (excluding drive time) averaged 11.4 ± 0.7 hours in duration. Participants reported to the mobile laboratory after the work shift, were weighed, provided a urine sample, and returned the monitors. Weather conditions were reported using the Fort Collins Weather Station Data Access (http://ccc.atmos.colostate.edu/~autowx/fclwx_access.php).

HIDALGO EQUIVITAL EQO2 LIFEMONITOR SYSTEM

Because of technical difficulties with the system (battery failure in the ingestible sensor owing to a manufacturing error in soldering), complete HR and core and chest skin temperature data for the entire work shift were collected on 29 of the 45 person-days. These variables are expressed as descriptive data to characterize physiological strain patterns during these days of wildland fire suppression. Physiological Strain Index (PSI) score was computed based on Moran et al.[8] A resting HR of 71 beats/min was used for all modeling.[8,9]

RETROSPECTIVE RESEARCH DATA

To characterize the differences in TEE and rH_2O between the current data set and a study cohort from 15 years earlier, data were obtained from 2 studies by Ruby et al.[1,2] The methods for tracer dose administration and analysis between the current and past studies are identical.

STATISTICS

All analysis was performed using SPSS for Windows Version 13 (Chicago, IL). Significance was set to probability values of less than .05. Data are reported as mean ± SD.

Results

BODY MASS

Differences in body mass were analyzed using a one-way analysis of variance. There was no change in morning body mass across the 3-day data collection period (77.3 ± 8.3, 76.9 ± 8.3, 77.5 ± 8.6, and 77.0 ± 8.9 kg for mornings 1, 2, 3, and 4, respectively; $P = .12$).

HEART RATE AND CORE AND CHEST SKIN TEMPERATURE

See Table 1 for a complete profile of HR, core and chest skin temperature, and PSI over the course of 3 days of wildland fire suppression.

ACTIVITY

Activity was higher on day 1 compared with days 2 and 3, and day 2 was higher than day 3 ($P < .05$; Figure 1). Activity intensity profiles for the 3 days can be observed in Figure 2.

TOTAL ENERGY EXPENDITURE AND WATER TURNOVER

The mean TEE was 19.1 ± 3.9 MJ/d, and the mean rH_2O was 9.5 ± 1.7 L/d. Individual participant data, as well as means for all energy expenditure variables, can be seen in Table 2. A retrospective analysis of the current data set compared with the 2002 wildland fire paper by Ruby et al[1] can be seen in Table 3.