ENERGY COST AND THERMAL CONTRIBUTION OF COMPONENTS OF PROTECTIVE FIREFIGHTER GEAR

by

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A THESIS

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ABSTRACT

Firefighter turn-out gear negatively impacts firefighters' ability to dissipate heat and increases energy expenditure consequently decreasing work tolerance and efficiency. The purpose of this study was to determine the contribution of individual components of firefighter turn-out gear to the energy expenditure and heat retention during work in a hot environment.

Male participants (n=8) (Mean ± SD: 24.8 ± 2.6 yr, 73.1 ± 9.8 kg, 181 ± 4 cm, 57.3 ± 8.8 ml•kg^{-1}•min^{-1} VO_2 max) worked for 40 min (12 min walk followed by 3 min of 10 arm curls) on a treadmill at a speed and grade eliciting 50% of VO_2 max in a heat chamber (WBGT: 33^{o}C, RH: 40-45%) while wearing firefighter turn-out gear and a breathing apparatus (SCBA). Energy expenditure was measured during work to assess the energy costs of five firefighter turn-out gear configurations (full gear, trousers, coat, SCBA alone, and peripherals: helmet, hood and gloves (HHG)).

Mean walking and arm-curl VO_2's were not significantly different ($p > 0.05$) among any of the gear combinations. Mean delta (T_{40}-T_0) heart rate (ΔHR) was significantly higher (p = 0.01) for full gear (85 ± 25 beats•min^{-1}) compared to trousers (53 ± 16 beats•min^{-1}), SCBA (57 ± 13 beats•min^{-1}), and HHG (58 ± 17 beats•min^{-1}). In addition, mean delta body core temperature (ΔT_{re}) was significantly higher ($p < 0.05$) for full gear (1.4 ± 0.4˚C) compared to coat (0.8 ± 0.3˚C), SCBA (0.8 ± 0.4˚C), and HHG (0.8 ± 0.2˚C). Ratings of Perceived Exertion (RPE) were significantly higher ($p < 0.05$) for full gear (9 ± 3) compared to trousers (6 ± 2), coat (6 ± 3), and HHG (6 ± 2).

Each component of the firefighter turn-out gear similarly increased VO_2 and hampered heat dissipation in a hot and humid environment. Although, the SCBA accounted for over half of the total weight of the firefighter gear, it made a similar contribution to the thermoregulatory demands as other pieces of equipment. Availability of lighter and safer protective clothing and SCBA could reduce physiological stress and potentially improve rescue time, but there appear no clear advantages to improving any particular piece of gear.

LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of variance
$beats•min^{-1}$	Beats per minute
cm	Centimeters
HR	Heart rate
$Kcals·h^{-1}$	Kilocalories per hour
kg	Kilogram
$L·min^{-1}$	Liter per minute
min	Minute
$ml·min^{-1}·kg^{-1}$	Milliliter per minute per kg
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
RER	Respiratory exchange ratio
SD	Standard deviation
T_{re}	Core temperature

VO_{2peak}	Peak oxygen uptake
VO_2	Volume oxygen consumption
vs.	versus
W	Watts
WBGT	Wet bulb globe temperature
Δ	Delta
$\geq$	Greater or less than

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INTRODUCTION

Firefighters are required to perform rescues under demanding circumstances while protected by heavy uniforms having limited flexibility and permeability to water in liquid or vapor form. These uniforms act as protective shields for their bodies while firefighters are performing rescues and fire suppression. However, clothing and gear have a negative impact on the firefighters' work capacity and thermoregulation due to both weight and reduced dissipation of heat produced during muscular activity. [(1, 2)]

Firefighters have a work tolerance time on average of 20 minutes during a fire rescue due to overheating, exertion, and limited oxygen supply carried by each firefighter. [(3)] Performing other rescues, such as emergency response and any follow-up procedures after fire suppression, requires less intense work, therefore the work tolerance is longer due to lower energy production rates for the firefighters.

Limited oxygen supply during rescue is not the only factor impacting firefighters' performance. The bulky and multi-layered uniform covering the entire body is another factor that restricts firefighters' endurance during rescues due to elevated energy cost and high resistance to heat loss. Therefore, the purpose of this study was to determine the contribution of various components of firefighter turn-out gear to energy costs and heat storage during work in a hot environment. It was hypothesized that self-contained breathing apparatus (SCBA) and coat would be the major contributors to energy consumption and generate the biggest thermal impact on firefighters, respectively.

METHODS

Eight healthy male participants volunteered for this study. Prior to testing, the participants' height (cm) and body mass (kg) were measured using a calibrated scale (Detecto Scales Inc., Brooklyn, NY) and stadiometer (Detecto, WebbCity, MO) and age (yr) were recorded. Body fat percentage was estimated using a skinfold caliper (Lange, Cambridge, MD) and a three-site method (chest, abdomen, and thigh). [4] Participants' characteristics are summarized in Table I. All procedures and risks were fully explained, and participants provided written informed consent before participation in accordance with the local Institutional Review Board. In addition, the participants were screened for risk factors using American College and Sports Medicine guidelines and the PAR-Q screening questionnaire.[5]

Prior to entering the study, the participants performed a graded maximal treadmill (Q55xt, Series 90; Quinton Instrument Co., Seattle, WA) test to determine maximal oxygen consumption (VO_2max). Respiratory gases were collected and analyzed with open-circuit spirometry (Vacu-med Vista mini-cpx, Vacumetrics Inc., Ventura, CA). The test consisted of 3-minute stages with an initial speed of 9.5 or 11 km•h^{-1}and initial incline of 0%. Treadmill speed and incline were increased every 3 minutes until three of the following four criteria were met: RER $\geq$ 1.1, ratings of perceived exertion of 19 or higher, a VO_2 plateau, or reaching at least 85% of the maximum predicted heart rate.

Due to high energy expenditure required of firefighters while performing rescues, the maximal oxygen consumption had to exceed 42 ml•kg^{-1}•min^{-1}. [4,5,6–8]

Therefore, in order to achieve a representative population sample, the maximal oxygen consumption of the participants had to exceed 42 $ml \cdot kg^{-1} \cdot min^{-1}$ in order to participate in this study.

Full participation required six lab sessions per participant, all sessions following the initial session were performed in a counterbalanced order and participants were encouraged not to engage in any strenuous exercise 24 hours prior to each trial.

Each trial took place in a hot environmentally-controlled space at 35°C wet bulb globe temperature (WBGT: dry = 36.8°C, wet= 33.6°C, globe = 36.5°C) and 40-45% relative humidity. For all trials, the participants self-inserted a rectal thermocouple (RET-1, Physitemp Instruments Inc., Clifton, NJ) covered with a sterile sheath (Reli On, MABIS Healthcare Inc., Waukegan, IL) approximately 8 centimeters past the rectal sphincter. For the baseline trial, the participants wore full firefighter turn-out gear (Lion Apparel, Janesville, WI), which included: pants, coat, hood (American Firewear Inc., Ohatchee, AL), helmet (ED Bullard Company, Cynthiana, KY), gloves (American Firewear Inc., Ohatchee, AL), and self-contained breathing apparatus (SCBA, SURVIVAIR Inc., Santa Ana, CA). For safety and comfort purposes and methods consistency of the study, the participants wore their own running shoes and socks. This configuration was referred to as "Full gear".

For one of the trials, participants wore firefighter's pants, a t-shirt and their own running shoes and socks, referred to hereafter as the "Trousers" configuration. For another trial, participants wore firefighter's coat, running shorts and their own running shoes and socks, referred to hereafter as "Coat". For a different trial, participants wore firefighter's self-contained breathing apparatus (SCBA) with t-shirt and running shorts and own running shoes and socks, referred to hereafter as "SCBA". One additional trial consisted of firefighter's helmet, gloves, hood with t-shirt and running shorts and own running shoes and socks, referred to hereafter as "Peripherals". Table II summarizes the firefighter turn-out gear components for each trial.

The five work trials consisted of 40 minutes walking on a treadmill at a speed and grade eliciting 45% to 50% of the participant's VO_2 without the gear, which was determined at the beginning of the first trial. The walking was interspersed with arm curls. For the first 12 minutes of each trial, participants' VO_2 was measured in order to assess the energy cost of the firefighter turn-out gear configuration, and referred to as "walking VO_2". Immediately after the 12-minute walk, the treadmill was stopped and participants performed 10 biceps curls during a 3-minute period. Three minutes after stopping the treadmill, the participants began walking again. The average VO_2 over the 3-minute period with the 10 arm curls was also measured and referred to as "arm-curl VO_2". The upper-body VO_2 was measured again at minute 27 for another 3 minutes to help ensure stable data. To ensure stable data, less than 10% in variation of the mean VO_2 for a data segment was allowed for a satisfactory measurement of the mean VO_2. The percentage changes of the walking and arm-curl VO_2 were calculated by dividing the mean VO_2 for each of the firefighter turn-out gear components by the VO_2max and multiplying by 100.

During each trial, heart rate (HR) and core temperature (T_{re}) were monitored and recorded every 5 minutes. In addition, every 5 minutes, participants were asked to give ratings of perceived exertion (RPE). [9] During the trials participants were not allowed to drink or eat in order to minimize any influence on the measurements.

Statistical Analyses

For each participant, an average RPE, HR and T_{re} were calculated for each of the five trials: full turn-out gear, trousers, coat, SCBA, and peripherals (hood, helmet, and gloves). In addition, for each of the trials, the differences between average RPE, HR, and T_{re} at time minute zero (e.g., T_0) and at the end of the trial, minute 40 (e.g., T_{40}), were calculated resulting in ΔRPE, ΔHR, and ΔT_{re}.

Arm-curl VO_2 was averaged for the two, three-minute arm curl sessions (min 12 to 15, and min 27 to 30) during each of the five trials. Walking VO_2 was averaged for the first 12 minutes of walking.

A series of one-way repeated measures ANOVA’s were calculated for ΔRPE, ΔHR, ΔT_{re}, arm-curl VO_2, and walking VO_2. When appropriate, Least Significant Difference (LSD) post-hoc procedures were performed in order to indentify differences in the variables in among different trials (suit configurations). All data were reported as the mean ± SD. Statistical significance was set at $p < 0.05$.

RESULTS

Core temperature (T_{re})

Repeated measures ANOVA identified significant differences among the trials for ΔT_{re} ($p < 0.01$). The post-hoc analysis identified a significantly ($p = 0.004$) higher ΔT_{re} during full turn-out gear (1.4 ± 0.4˚C) compared to coat (0.8 ± 0.3˚C), SCBA (0.8 ± 0.4˚C) ($p = 0.002$), and peripherals (0.8 ± 0.2˚C) ($p = 0.001$). No other differences were seen. Figure 1 illustrates average T_{re} over time during the 40-min trials.

Heart Rate (HR)

The repeated measures ANOVA identified a significant difference between trials for ΔHR ($p < 0.01$). The post-hoc analyses identified a significantly ($p = 0.04$) higher HR during full turn-out gear (85 ± 25 beats•min^{-1}) compared to the trousers (53 ± 16 beats•min^{-1}) trial. Also, the post-hoc analysis identified a significantly ($p = 0.03$) higher ΔHR during full turn-out gear compared to SCBA (57 ± 13 beats•min^{-1}), and a significantly ($p = 0.04$) higher ΔHR during full turn-out gear compared to peripherals (58 ± 17 beats•min^{-1}). No other differences were seen. Figure 2 illustrates average HR over the 40-min trials.

Energy cost

As listed in Table II, the highest energy cost for walking was associated with the full gear ensemble (25.80 ± 6.27 ml•kg^{-1}•min^{-1} or 658 ± 204 W). The highest energy expenditure for arm curl was established while wearing the SCBA (12.9 ± 2.74 ml•kg^{-1}•min^{-1}or 322 ± 46 W). Table II summarizes the weight difference of full gear and individual gear pieces and the cost energy for arm curls and walking for each firefighter turn-out gear combination.

Ratings of Perceived Exertion (RPE)

Repeated measures of ANOVA identified a significant difference between trials for ΔRPE ($p < 0.01$). The post-hoc analysis identified a significantly ($p = 0.005$) higher ΔRPE during full turn-out gear (9 ± 3) compared to trousers (6 ± 2) ($p = 0.005$), coat (6 ± 3) ($p = 0.004$), and peripherals (6 ± 2) ($p = 0.011$). No other differences were seen. Figure 3 presents the average changes in ΔRPE over 40-min trials.

Arm-curl and walking VO_2

Results from the repeated measures ANOVA identified no significant main effect between trials for arm-curl VO_2 ($p = 0.46$) or for walking VO_2 ($p = 0.45$). Mean arm-curl VO_2 ranged from 11.1 ml•kg^{-1}•min^{-1} or 281 W (coat) to 12.9 ml•kg^{-1}•min^{-1} or 322 W (SCBA), while mean walking VO_2 varied from 22.8 ml•kg^{-1}•min^{-1} or 518 W (coat) to 25.8 ml•kg^{-1}•min^{-1} or 658 W (Full gear). No significant differences ($p > 0.05$) were found among the clothing components (Trousers, Coat, SCBA and Peripherals) for any of the measurements.

DISCUSSION

Firefighter gear is bulky and multi-layered. Equipment companies are continuously seeking ways to make firefighter clothing and equipment permeable to enhance metabolic heat loss through evaporation of sweat, and lighter and less bulky to enhance wearer energy efficiency. The purpose of this study was to determine if any of the sub-components made inordinate contributions to the total energy costs and heat storage during work in a hot environment. Our data on the energy costs and interference with heat dissipation were similar among the sub-components, but our firefighters had above average fitness level, 57.3 $ml \bullet kg^{-1} \bullet min^{-1}$ (4.1 $L \bullet min^{-1}$).

In previous research by McLellan et al.[3], the test trial duration typically did not exceed 20 min, which coincides with the average time a firefighter spends during a rescue due to limited oxygen supply provided by SCBA. The present study doubled the time trial to 40 min per trial in an effort to determine more clearly any physiological effects of each piece of firefighter turn-out gear. Heat stress increases T_{re} and HR over time independent of exercise. However, in hot environments with extra weight carried during rescues, firefighters' HR and T_{re} increase dramatically. [12] Under heat strain plus heavy work, the cardiovascular system must transport blood to the working muscles and to the extremities; however, the impermeability of firefighter turn-out gear makes it difficult to dissipate heat.

During the full turn-out gear trial, heat could not be dissipated fast enough to balance out heat production, resulting in a high T_{re} (38.8 ± 0.2˚C) and high HR (177 ± 17.7 beats•min^{-1}) at the end of 40 min. The increase in T_{re} was 1.4˚C, and for HR was 85 beats•min^{-1} over the 40 min during the full turn-out gear trial. Previous research supports a linear increase in HR and T_{re} over time [11] in hot environments when wearing full turn-out gear [12] ; therefore continued work would be expected to put firefighters in dangerous levels of heat storage and cardiovascular strain. The core temperature and HR increase over the 40 minutes, respectively, was: Trousers: 1.0˚C and 53 beats•min^{-1}, Coat: 0.8˚C and 66 beats•min^{-1}, SCBA: 0.8˚C and 57 beats•min^{-1}, and Peripherals: 0.8˚C and 58 beats•min^{-1}. High heart rates observed over longer periods of time indicates the participants' ability to handle physiological stress as well as high anxiety associated with heavy work in hot environments. [13]

McLellan al. [3] investigated the heat stress of long pants or shorts under firefighting turn-out gear in a hot environment of 35°C, 50% humidity. After 20 minutes of exercise the absolute VO_2 was 1.97 ± 0.11 L•min^{-1} while wearing full turn-out gear with shorts under trousers. Similar results were found in this study, walking VO_2 during the 40 minutes of exercise in a hot, humid environment was 1.90 ± 0.6 L•min^{-1} (658 W). Walking VO_2 when wearing SCBA alone was virtually the same at 1.87 ± 0.49 L•min^{-1} (651 W). In our very fit subjects, these values correspond to 46% and 45% of VO_2 max, respectively. The weight difference between full turn out gear and SCBA-alone was 6.9 kg; but each evidenced almost equal demands of VO_2. Extra weight increased physical demands of the different pieces of equipment. Walking VO_2 for trousers accounted for 42% of VO_2 max (1.72 ± 0.38 L•min^{-1}, 611 W), walking in the coat accounted for 40.5% (1.66 ± 0.33 L•min^{-1}, 578 W) and peripherals for 40.5% of VO_2 max (1.66 ± 0.44 L•min^{-1}, 579 W). It appears that oxygen demands were almost equal between the coat and peripherals due to similar motion restrictions through extremities. We did not test ladder or stair climbing. In these situations, VO_2 would likely be responsive to the weight carried.

When compared clothed with unclothed, Sawka et al. (14) found arm crank absolute VO_2 was 1.57 ± 0.19 $L \cdot min^{-1}$ and leg cycle VO_2 was 1.64 ± 0.19 $L \cdot min^{-1}$ after 60 minute trials in an ambient environment of 24˚C and 20% humidity, at 60% of peak VO_2, while wearing shirts and a t-shirt. The results of our study found walking VO_2 was 1.9 ± 0.60 $L \cdot min^{-1}$ (658 W) and arm-curl VO_2 was 0.9 $L \cdot min^{-1}$ (318 W) after 40 minutes of exercise in a hot environment 35˚C and 45% humidity, at 45% of peak VO_2, while wearing full turn out gear. The difference in peak work rates between clothed and unclothed was due to increased clothing weight and restriction of movement. (15)

Ftaiti et al. (16) studied the physiological effects on firefighters when wearing one of five different jackets, one leather and four different textile jackets in an ambient environment of 22˚C and 56% humidity. Heart rate ranged from 161 $beats \cdot min^{-1}$ without jacket to 187 $beats \cdot min^{-1}$ with leather jacket during the 15 minute trials at 70% of maximum oxygen consumption. Although the environment for current study was 35°C, at 45% to 50% of maximum VO_2, the observed heart rate for the coat trial was 152 $beats \cdot min^{-1}$. In Ftaiti et al. (16), the leather jacket did not allow the heat transfer as well as turn-out gear coat. Evaporation was restricted and sweat was encapsulated between the skin and leather jacket resulting in higher work load, respectively higher heart rate. The synergistic impact of heat storage and work rate makes comparisons among studies difficult.

Participants' mean RPE was 14 while wearing full firefighter turn-out gear which is between "somewhat hard" and "hard" while wearing a total of 17.5 kg of gear. However, the mean RPE for the trousers and peripherals was 13 which is the equivalent of "somewhat hard".

The mean RPE value for coat and SCBA trials was 12, equivalent of the perceived exertion between “Somewhat hard” and “light”. The SCBA alone weighed 10.6 kg, but the RPE value was lower than just wearing the peripherals. Similarly, McLellean et al. [3] suggested that RPE surprisingly did not differentiate the major changes in HR and T_{re} while exercising in a 35˚C environment. Failure to distinguish changes in HR, T_{re}, and energy cost might be due to the limited sweat evaporation during the trials [17], and participants focusing on the level of discomfort rather than the actual physical demand. Participants’ average maximal oxygen consumption in this study was 57.3 $ml•kg^{-1}•min^{-1}$ indicating an above average fitness levels, which might be another explanation of failure to register differences in perceptual ratings for our relatively modest energy demands.

Although there was no significant difference in mean VO_2 among the trials, wearing full turn-out gear registered a mean absolute VO_2 of 0.91 $L•min^{-1}$ for arm curls and 1.9 $L•min^{-1}$ during walking. Sköldström et al. [18] found no significant difference in oxygen uptake with full turn-out gear (1.2 $L•min^{-1}$) and without it (0.8 $L•min^{-1}$) in an ambient environment 15˚C and a hot environment of 45˚C, humidity 15%, walking for 60 minutes at 3.5 $km•h^{-1}$, representing 20 to 30% of the maximal oxygen uptake. Doubtlessly the lower relative effort and likely less fit subjects in Sköldström’s study [18] resulted in lower values.

In temperate environments (21 - 24˚C), Holmér et al. [19] found high energetic demands of 33 to 43.8 $ml•kg^{-1}•min^{-1}$ for different firefighting activities performed on a special test ground, while wearing full turn-out gear during an average of 22 min of exercise. In a fire ensemble but without the SCBA, Baker et al. [20], found that energy cost of walking at 7 $km•h^{-1}$ was about 40 $ml•kg^{-1}•min^{-1}$ and the energy cost of walking at 5 $km•h^{-1}$ was 26.2 $ml•kg^{-1}•min^{-1}$ during 12 min of exercise when overall VO_2 was measured and subjects were allowed to drink water ad libitum.

Compared to our study where, after 40 minutes of exercise at 45 to 50% of VO_2 max, with speeds ranging from 5.2 km•h^{-1} to 5.7 km•h^{-1} and inclines ranging from 2.7 to 4.5% in hot environment of 35˚C and 45% humidity, walking VO_2 was at 25.8 ml•kg^{-1}•min^{-1} similar to Baker's 5 km•h^{-1} walk speed.

The mean oxygen consumption during arm-curl of 12.9 ml•kg^{-1}•min^{-1} (322 W) and the mean walking VO_2 was 25.9 ml•kg^{-1}•min^{-1} (651 W) during SCBA trial. The total weight of the SCBA was 9.5 kg. Louhevaara et al. (21) found higher energetic demands of a 15.5 kg SCBA during heavy exercise in a temperate environment of 21 to 25˚C with an overall VO_2 of 44.3 ml•kg^{-1}•min^{-1} (1127 W) after 20 minutes of exercise. During sustained exercise in a hot environment, extra weight added by SCBA increases VO_2 and carbon dioxide levels resulting in an increase cardiac output.(22, 23) Furthermore, HR and T_{re} increase as a result of the high oxygen demands required by the extra weight carried while wearing the SCBA. Although in the present study the SCBA was not functional, studies (22) have indicated that filtering devices of SCBA can considerably decrease physical work capacity of firefighters. When VO_{2max} was measured with firefighter turn-out gear and SCBA ensemble and unclothed, Dreger et al. (24), found an association between lower VO_{2max} and decrease tidal volume due to decreased peak ventilation.

CONCLUSIONS

Each of the sub-components of the firefighter turn-out gear similarly increased VO_2 and hampered heat dissipation in a hot and humid environment. The SCBA accounted for more than half of the total weight of the firefighter gear and made as high a thermoregulatory demand as full gear. Likewise, the energy costs for SCBA were as high as the full gear. Availability of lighter and safer protective clothing and SCBA could reduce the physiological stress and potentially improve rescue time, but there appear no clear advantages to improving any particular piece of gear.

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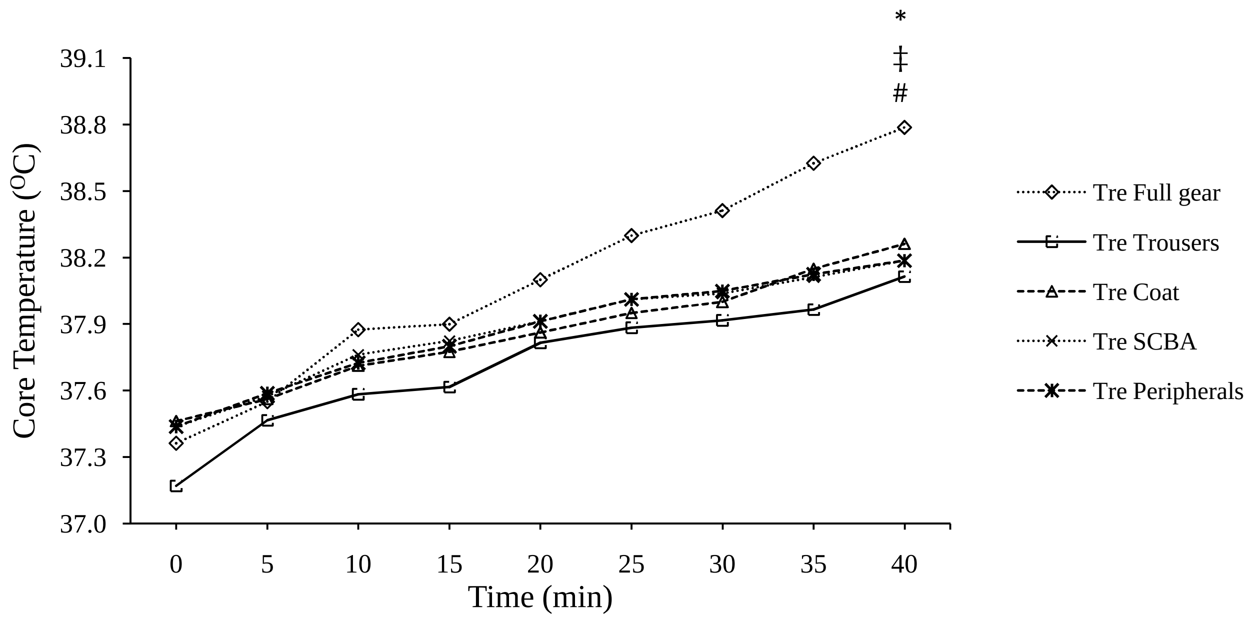
Figure captions

Figure 1. Mean rectal temperatures during 40 min of walking and arm curls, for each of five turn-out configurations. Mean rectal temperature standard deviation for five turn-out configurations was 0.4^{o}C. * Indicates significant difference ($p < 0.05$) between Full gear and Coat, ‡ Indicates significant difference ($p < 0.05$) between Full gear and SCBA, # Indicates significant difference ($p < 0.05$) between Full gear and Peripherals. Core temperatures were not significantly different among the sub-configurations, ($n = 8$).

Figure 2. Mean HR during 40 minutes of walking and arm curls, for each of five turn-out configurations. Mean HR standard deviation for five turn-out configurations was 19 beats•min^{-1}. * Indicates significant difference ($p < 0.05$) between Full gear and Trousers, ‡ Indicates significant difference ($p < 0.05$) between Full gear and SCBA, # Indicates significant difference ($p < 0.05$) between Full gear and Peripherals. HRs were not significantly different among the sub-configurations, ($n = 8$).

Figure 3. Mean change in RPE (mean ± SD) pre to post during 40 minutes of walking and arm curls, for each of five turn-out configurations. *Indicates a significant difference ($p < 0.05$) between Full gear and Trousers, ‡ Indicates significant difference ($p < 0.05$) Full gear and Coat, and # Indicates significant difference ($p < 0.05$) Full gear and Peripherals. RPE was not significantly different among the sub-configurations, ($n = 8$).

Figure 1



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Tre Peripherals

Figure 2

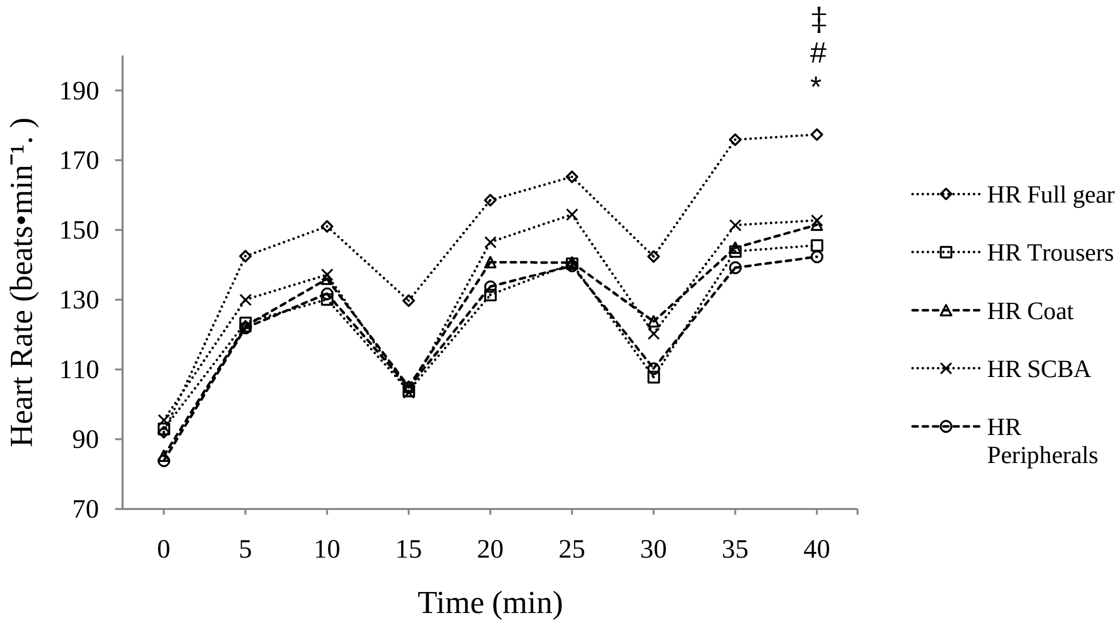
‡
#
*
190
170
150
130
110
90
70
0
5
10
15
20
25
30
35
40
Heart Rate (beats•min⁻¹.)
Time (min)
HR Full gear
HR Trousers
HR Coat
HR SCBA
HR Peripherals

Figure 3

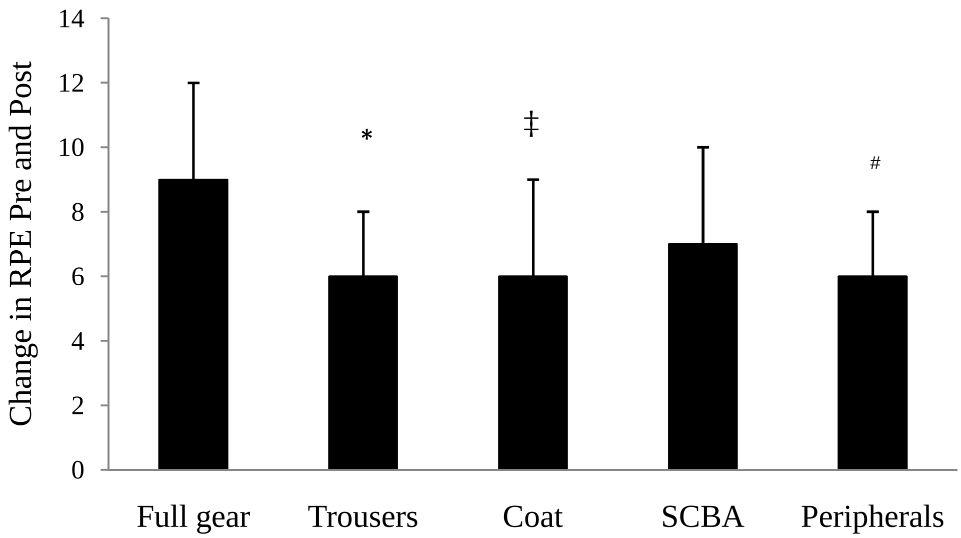
Change in RPE Pre and Post
14
12
10
8
6
4
2
0
*
‡
#
Full gear
Trousers
Coat
SCBA
Peripherals

Table I.Mean (SD) physical characteristics of the participants (men, n = 8).

Variables	Mean ± SD
Age (yr)	24.8 ± 2.6
Weight (kg)	73.1 ± 9.8
Height (cm)	180.7 ± 4.3
Body fat (%)	11.0 ± 4.9
VO2max (ml•kg^{-1}•min^{-1})	57.3 ± 8.8

Table II. Total weight of each firefighter sub-component (Trousers, Coat, SCBA, and Peripherals). Firefighter gear components for the five trials. X Indicates the component used in individual trials.

Firefighter gear components	Trousers	Coat	SCBA	Peripherals	Full turn-out gear
Full gear (Lion Apparel, Janesville, WI)					X
Pants (American Firewear Inc., Ohatchee, AL)	X				X
Coat (American Firewear Inc., Ohatchee, AL)		X			X
Helmet (E D Bullard Company, Cynthiana, KY)				X	X
Hood (American Firewear Inc., Ohatchee, AL)				X	X
Gloves (American Firewear Inc., Ohatchee, AL)				X	X
SCBA (SURVIVAIR Inc., Santa Ana, CA)			X		X
T-shirt, running shorts, shoes and socks	X	X	X	X	X
Weight (kg) of each firefighter sub-component	1.7	2.0	10.6	1.7	17.5

Table III. Mean (SD) energy cost for each configuration of firefighter turn-out gear (n = 8). No significant difference ($p > 0.05$) between the full gear and any of the other configurations (n = 8).

Configurations	Arm-curls VO2 (kcal·h⁻¹)	Walking VO2 (kcal·h⁻¹)	Arm-curls VO2 (Watts)	Walking VO2 (Watts)
Trousers	248.6 ± 57.6	517.3 ± 113.4	289 ± 67	611 ± 132
Coat	241.6 ± 55.5	496.8 ± 100.3	281 ± 65	578 ± 117
SCBA	276.8 ± 39.5	560.2 ± 148.1	322 ± 46	651 ± 172
Peripherals	250.0 ± 33.2	497.7 ± 131.1	291 ± 39	579 ± 152
Full turn-out gear	273.7 ± 74.5	556.2 ± 175.6	318 ± 87	658 ± 204