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The Effect of Full Turnout Gear and Weighted Vest on Firefighter's Responses During an Ability Test

Koulla M Parpa*, Marcos M Michaelides

Department of Sports Science, UCLan University, Pyla, Cyprus

*Corresponding author: Koulla M Parpa

kparpa@uclan.ac.uk

Department of Sports Science, UCLan University Pyla, Cyprus

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Abstract

Background: The purpose of the current study was to compare the effect of the different gear worn on the firefighters' internal load. The study examined the HR kinetics, blood lactate, and subjective responses on a firefighting simulated ability test.

Methods and findings: A total of 90 firefighters were randomly divided into three groups (Group-1 weight vest, Group-2 protective ensemble in full turnout gear, Group-3 protective ensemble in full turnout gear, and self-contained breathing apparatus). One-way Multivariate Analysis of Variance was used to assess the physiological and subjective responses among the three gear groups. Upon finishing the AT, firefighters reported an average RPE of 15 ± 2, where 15 represents " heavy" on the Borg scale. The average lactate was 12.98 mmol/l ± 2.36 mmol/l. The average HR during the tasks was (183 ± 9) bpm, which was calculated to be 99.08% ± 4.71% of the age estimated HR max (184 ± 5) bpm.

Result: The results demonstrated that there was a significant multivariate effect of firefighters' HR over time, ($F(7,41)=617.26$, $p<0.01$). Furthermore, repeated measures contrast analysis demonstrated that the HR before the beginning of task 1 was significantly higher ($p<0.01$) than the resting HR and significantly lower ($p<0.01$) than the heart rates reported after each task. There was no significant multivariate interaction effect between time and gear group ($F(14,82)=1.22$, $p=0.27$).

Conclusion: It is evident that firefighting can be as strenuous with a weight vest as with full turnout gear and breathing apparatus. Therefore, a vest with the same weight as the complete protective outfit could be used effectively to simulate gear during simulated fire fighting under ambient conditionsy.

Keywords: Simulated fire fighting; Protective outfit; Gear

Introduction

It is widely recognized that firefighting is both physically and mentally strenuous [1-2]. In particular, firefighters have to encounter a range of unpredictable settings and conditions characterized by high temperatures, flames, environmental pollutants, and toxic by-products produced by the fire. Accordingly, numerous studies affirm that firefighters' extreme physiological demands during fire fighting are augmented by the weight of their protective gear and Self-Contained Breathing Apparatus (SCBA) [3-5]. Research affirms that wearing protective clothing and respirators in a neutral environment could result in significant and potentially dangerous thermoregulatory and cardiovascular stress, even at low work intensities [6]. Although the turnout gear is necessary for protection, fireproof protective clothing has limited water vapour permeability that prevents the moisture and heat produced by the body from escaping, which may result in a condition called uncompensable heat stress [7]. During this condition, the evaporative heat loss needed to sustain a thermal state exceeds the maximal evaporative capacity of the environment [8]; thus, the sweating response fails to serve its purpose, and therefore the body temperature rises. Furthermore, as a result of excessive fluid loss, the body becomes more susceptible to severe dehydration, which in turn may lead to cognitive and physiological performance decreases [9-11]. Several investigators thoroughly examined the firefighters' physiological responses associated with firefighting activities. In particular, research demonstrated that firefighting led to maximal heart rate due to an increased metabolic rate when different fire jackets were examined compared to significantly lower heart rate responses without a protective jacket [12]. Furthermore, the type of clothing worn under the protective bunker pants and jacket had a negligible effect on cardiovascular function [13]. The firefighters' physiological responses are usually investigated by employing various simulated firefighting training tests as well as while performing firefighting tasks in real live fires [14-22]. Common simulated firefighting tests include a modified combat test, simulated hospital patient rescue, simulated shipboard fire, and in-flight emergency responses [16,23-25]. Although the purpose and the settings among the aforementioned tests varied, the firefighters had to perform a similar set of tasks. Some of these common firefighting tasks included stair climbing, chopping simulation, and victim drag, pulling charged hoses, and carrying heavy equipment. All the tests used to simulate firefighting were characterized by a sequence of events performed in sporadic intervals of strenuous effort. Currently, the Candidate Physical Ability Test (CPAT) is considered the most validated and reliable firefighting simulation [17]. During the eight events included in the test, the candidate must wear a 22.68 kg weighted vest to simulate firefighters' protective clothing and equipment weight. Although the vest has the same weight as the firefighters' protective clothing and SCBA, to our knowledge, no studies compared the physiological and subjective responses (Rate of Perceived Exertion-RPE) among firefighters with a weight vest compared to the protective clothing and SCBA. Although performance on simulated tests is standardized based on the time of completion, the turnout gear used to test firefighters and recruits vary from one test to another. Thus, the purpose of the current study was to compare the effect of the different gear worn on the firefighters' internal load. Therefore, the present study examined the HR kinetics, blood lactate, and subjective responses on a fire fighting simulated Ability Test (AT) among firefighters with a weight vest, firefighters in full turnout gear, and firefighters in full turnout gear breathing through SCBA. Thus, the null hypothesis that there was no main effect of gear in the population was examined.

Methods

Firefighters were administered the AT that the local Fire Department designed to test the performance of firefighters on simulated conditions and used as a criterion for recruiting new firefighters. During the administration of the AT, male firefighters from three shifts and six stations attended the main fire station. The test was administered by the same instructors and included six consecutive timed tasks. It should be noted that the test was administered to all the firefighters as this was part of their assessment. The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

Subjects

A total of 90 firefighters participated in the study and were randomly divided into three groups. All groups added 22.68 kg to their actual body weight. Group-1 wore a weight vest (V-Max™, 22.68 kg, Short Narrow™), sports clothing (short pants and T-shirt), and tennis shoes. Group-2 wore their protective ensemble in full turnout gear and SCBA, without the positive pressure mask. Group-3 wore their protective ensemble in full turnout gear and breathed through the SCBA. The turnout gear included: SCBA (ISI Viking™), SCBA Harness, comprised of shoulder and waist straps, Helmet (Morning Pride™, Plus Series, model: HDOBF00HB), Coat and pants (Morning Pride™), Outer shell (7.5 oz Ripstop PBI® Enhanced Water Repellent), Thermal layer (Spun Filament Nomex® Face Cloth/Light Kevlar® Batt) and Moisture barrier (PTFE on 50% Basofil®, 25% Neta®, 25% Para Aramid®). Groups (2-3) weighed with and without the gear to ensure that the extra weight was the same as the group with the weight vest. If the protective ensemble was not as heavy, weight was added to ensure that they carried the required load of 22.68 kg. Even though the test was administered to all the firefighters as part of their assessment by the fire department, their participation in the study was completely voluntary. Therefore, each participant was briefed on the procedures and signed informed consent before data collection. Ethical guidelines were followed according to the Helsinki Declaration's ethical standards, and a Research Institutional Review Board approved all procedures.

Ability test procedures

The test included six consecutive timed tasks. The total time to complete the test and the time of each task were recorded. The consecutive AT tasks were as follows

Task-1-Stair climb: The first task involved ascending and descending one flight of stairs consisting of twelve standard steps (24 × 30.5 cm) eight times.

Task-2-Rolled hose lift and move: The second task involved moving six rolls for a distance of 4.1 m. Each rolled hose was 9.53 kg, 15.24 meters long and 7 cm wide. The rolls were moved, one at a time, from the ground and set upon a bench. When all six rolls were placed on the table, the firefighters took one step back from the table. The firefighters then moved the six rolls, one at a time, back to the starting position on the floor and placed them in stacks of two rolls as they found them. They were required to stack the rolls evenly and neatly. Each roll had to be set down. No dropping or throwing of the rolled hoses was allowed.

Task-3-Keiser sled: The third task involved striking a 68.8 kg I-beam on a Keiser Sled (Keiser® Corporation, Fresno, CA) to a distance of 1.50 m with a 4.1 kg sledgehammer. The firefighters used over-the-head swinging motions to strike the I-beam. Pulling or pushing on the weight to move it faster was not allowed.

Task-4-Hose pull and hydrant hookup: During the fourth task, the firefighters entered a 2 × 2 m square painted on the concrete next to a fire hydrant and pulled an uncharged (dry) 7 cm wide fire hose, hand over hand, to a length of 31.5 m. After the hose was in the square, the firefighter had to hook the fire hose to the hydrant. During the process, firefighters removed the small cap from the fire hydrant with their hands and threaded a coupling from the hose onto the hydrant. The coupling had to be threaded on until it could no longer turn by hand. To finalize the fourth event, firefighters removed the coupling by hand and replaced it with the cap that was initially removed from the hydrant. The firefighters were not allowed to go outside of the square to perform the task, and the whole hose had to be placed within the 2 × 2 square.

Task-5-Rescue mannequin drag: the fifth task included dragging an 82 kg rescue mannequin for 15.7 m with both hands. The firefighters approached the mannequin from behind, lifted it from the shoulders, and dragged it by walking backwards. The event was considered complete when the feet of the rescue mannequin crossed the 15.7 m line.

Task-6-Charged hose advance: Upon completion of the dummy drag, the firefighters picked up a nozzle connected to a charged 4.4 cm hose and advanced the line for 15.24 meters. When the nozzle of the charged line crossed the finish line, the timing for the events was stopped. At this point, the total test time was recorded.

Heart rate determination

During the data collection, all firefighters were equipped with heart rate monitors. Resting HR, HR right before the beginning of the AT, HR at the end of each task, and HR at the end of the AT were recorded.

RPE and blood lactate determination procedures

The firefighters were given four minutes to recover immediately after the AT. During that period, they were asked to provide the RPE for the test based on a 15-point scale (perceptions of exertion range from 6-20) [26]. In addition, they prepared for lactate determination. The preparations involved washing their hands with soapy water and drying them thoroughly to get rid of any sweat left on the finger that might cause false results. Four minutes following completion of the AT, an auto lancet device armed with an ultra-fine gauge lancet was placed against the middle or ring finger pad. The first blood drop was wiped off, and the finger pad was squeezed, with light pressure, to form a second drop. The strip attached to the blood lactate measuring meter (Lactate Plus NOVA biomedical TM) was touched to the second drop. The blood volume and the test time needed were 0.6 µL and 13 seconds, respectively. The lactate analyzer was calibrated before each test day as instructed by the user manual.

Statistical analysis

SPSS 26.0 for Windows (SPSS Inc., Chicago) was used for the analysis of the results. One-way Multivariate Analysis of Variance (MANOVA) was used to assess the physiological differences among the three gear groups during the AT. One-between, one-within repeated measures multivariate analysis of variance was conducted to examine the impact of gear on HR response over the six firefighting tasks. Before the repeated MANOVA analysis, normality, and homogeneity of variances, assumptions for the HR variables were examined. The normality assumption based on the Shapiro-Wilk tests was met. Brown and Forsythe's test for homogeneity of variance demonstrated no significant difference in the variance of the HR measurements ($p>0.05$). Statistical significance was accepted at $p<0.05$.

Results

The firefighters had an average age of (33 ± 7) years, and their age ranged from (22-55) years. The descriptive statistics are presented in **Tables (1-2).**

Table 1: Descriptive statistics of firefighters.

Variable	N	M	SD	Max	Min
Height (cm)	73	181.16	6.62	198.12	162.56
Body Weight (kg)	86	97.04	15.51	145.15	70.31
Age (years)	89	33	7	51	22
BMI (kg/m2)	73	29.55	3.67	38.5	22.5
Resting SBP (mmHg)	72	134	13	170	110
Resting DBP (mmHg)	72	87	10	110	68

Note: BMI:Body Mass Index, SBP:Systolic Blood Pressure, DBP:Diastolic Blood Pressure, Cm:Centimeters, kg:kilograms.

Table 2: The descriptive statistics of firefighters in gear groups.

Variable	Vest		Gear		Gear (air)	
	M	SD	M	SD	M	SD
Body Weight (kg)	217.32	32.56	212.73	38.9	205.17	27.89
Age (years)	34	7	34	7	32	4
Body Fat%	23.25	5.77	23.45	5.4	21.58	5.51
BMI (kg/m2)	29.99	3.5	29.28	4.21	28.63	3.08
Resting SBP (mmHg)	134	12	137	14	129	11
Resting DBP (mmHg)	86	8.95	87	11	85	9
Resting HR (bpm)	71	11	74	11	71	20
Hip Circumference (cm)	107.6	6.3	108.6	8.5	109.2	7.4
Waist Circumference (cm)	99	11	97.7	11.2	91.5	7.4

Note: BMI:Body Mass Index, SBP:Systolic Blood Pressure, DBP:Diastolic Blood Pressure, Cm:Centimeters, Kg:kilograms. The Gear and Gear (air) groups were in full turnout gears. The Gear (air) group had the positive pressure mask on and used the SCBA to breath.

Analysis for AT performance

Table 3. presents the data collected during the AT of all firefighters despite their gear. Although the AT was performed consecutively, the time of each task was recorded to evaluate performance on individual tasks. In addition, the HR was recorded at the end of each of the six tasks. Upon finishing the AT, firefighters reported an average RPE of 15 ± 2, where 15 represents "hard (heavy)" on the Borg scale [26]. The average lactate was (12.98 ± 2.36) mmol/l. The average HR during the tasks was (183 ± 9) bpm, which was calculated to be 99.08% ± 4.71% of the age estimated HR max (184 ± 5) bpm.

Table 3: The firefighter's physiological and performance responses on the AT test.

Variable	N	M	SD	Max	Min
AT time (min)	79	7.07	1.76	13.35	4.4
Stair Climb (min)	69	1.58	0.44	3.38	1.03
Rolled Hose Lift and Move (min)	69	1.35	0.36	2.69	0.5
Keiser Sled (min)	69	0.48	0.34	1.55	0.12

Hose Pull and Hydrant Hookup (min)	69	0.84	0.38	2.1	0.12
Rescue Mannequin Drag (min)	69	0.19	0.09	0.57	0.1
Charged Hose Advance (min)	69	0.11	0.03	0.18	0.06
Initial-HR (bpm)	65	128	24	174	72
Stair Climb-HR (bpm)	66	183	11	206	126
Rolled Hose Lift and Move-HR (bpm)	66	177	11	204	148
Keiser Sled-HR (bpm)	66	189	9	206	170
Hose Pull and Hydrant Hookup -HR (bpm)	66	178	11	196	151
Rescue Mannequin Drag-HR (bpm)	66	182	9	198	155
Charged Hose Advance -HR (bpm)	66	186	9	202	166
Average Hr of the Six Events-HR (bpm)	66	183	9	198	159
Age Estimated Max HR (bpm)	90	184	5	193	172
Lactate (mmol/l)	63	12.98	2.36	18.7	8.8
RPE	67	15	2	19	12
Note: HR:Heart Rate, BPM:Beats Per Minute, Min:Minutes, RPE:Rate of Perceived Exertion.					

Comparing the responses of the three groups

One-way Multivariate Analysis of Variance of Variance (MANOVA) was performed to compare the multivariate means of the total AT, the time, the individual times for the six firefighting tasks, lactate, and RPE, grouped by gear. Overall results demonstrated no significant difference among the 3-gear groups, ($F(18,94)=1.08$, $p=0.38$, Wilk's $\Lambda=0.68$). The values of the aforementioned variables are summarized for firefighters in groups (1-3), in **Tables (4-6)**, respectively.

Table 4: The Physiological and Performance Responses for Firefighters in Group-1.

Variable	N	M	SD	Max	Min
AT time (min)	39	6.89	1.86	12.06	4.4
Stair Climb (min)	36	1.6	0.5	3.38	1.03
Rolled Hose Lift and Move (min)	36	1.35	0.42	2.69	0.5
Keiser Sled (min)	36	0.42	0.28	1.44	0.12
Hose Pull and Hydrant Hookup (min)	36	0.8	0.32	1.39	0.37
Rescue Mannequin Drag (min)	36	0.18	0.05	0.31	0.11
Charged Hose Advance (min)	36	0.11	0.03	0.17	0.06
Lactate (mmol/l)	33	13.03	2.21	17.5	8.8
RPE	32	15	1	18	12
Note: Min: minutes, RPE: Rate of Perceived Exertion.					

Table 5: The Physiological and Performance Responses for Firefighters in Group-2.

Variable	N	M	SD	Max	Min
AT time (min)	28	7.39	1.7	13.35	4.42
Stair Climb (min)	23	1.62	0.36	2.48	1.1
Rolled Hose Lift and Move (min)	23	1.34	0.3	2.38	0.56
Keiser Sled (min)	23	0.55	0.37	1.55	0.23
Hose Pull and Hydrant Hookup (min)	22	0.88	0.42	2.1	0.38
Rescue Mannequin Drag (min)	23	0.2	0.1	0.52	0.1
Charged Hose Advance (min)	23	0.11	0.04	0.18	0.06
Lactate (mmol/l)	22	12.95	2.79	18.7	9.1
RPE	23	15	2	19	13
Note: Min:Minutes, RPE:Rate of Perceived Exertion.					

Table 6: The Physiological and Performance Responses for Firefighters in Group-3.

Variable	N	M	SD	Max	Min
AT time (min)	12	6.94	1.57	10.45	5.13
Stair Climb (min)	10	1.48	0.36	2.17	1.1
Rolled Hose Lift and Move (min)	10	1.33	0.26	2	1.06
Keiser Sled (min)	10	0.55	0.38	1.44	0.28
Hose Pull and Hydrant Hookup (min)	10	0.77	0.35	1.21	0.12
Rescue Mannequin Drag (min)	10	0.22	0.14	0.57	0.13
Charged Hose Advance (min)	10	0.1	0.03	0.17	0.07
Lactate (mmol/l)	9	12.87	1.96	15.9	10.1
RPE	11	15	2	17	12
Note: Min:Minutes, RPE:Rate of Perceive Exertion.					

One-between, one-within repeated measures multivariate analysis of variance was conducted to examine the impact of gear on HR response over the six firefighting tasks. Resting HR and HR at the beginning of the AT were included in the analysis. The results demonstrated that there was a significant multivariate effect of firefighters' HR over time (stages of the AT), ($F(7,41)=617.26$, $p<0.01$ Wilk's $\Lambda=0.79$). Furthermore, repeated measures contrast analysis demonstrated that the HR before the beginning of task 1 was significantly higher ($p<0.01$) than the resting HR and significantly lower ($p<0.01$) than the heart rates reported after each task. There was no significant multivariate interaction effect between time and gear group ($F(14,82)=1.22$, $p=0.27$, Wilk's $\Lambda=0.68$), demonstrating that none of the groups' HR changed differently over time. In addition, there was no significant difference, ($F(2,47)=0.53$, $p=0.22$), **Table 7.** among the three gear groups concerning their overall HR response. **Figure 1.** presents the HR responses of the three gear groups. The

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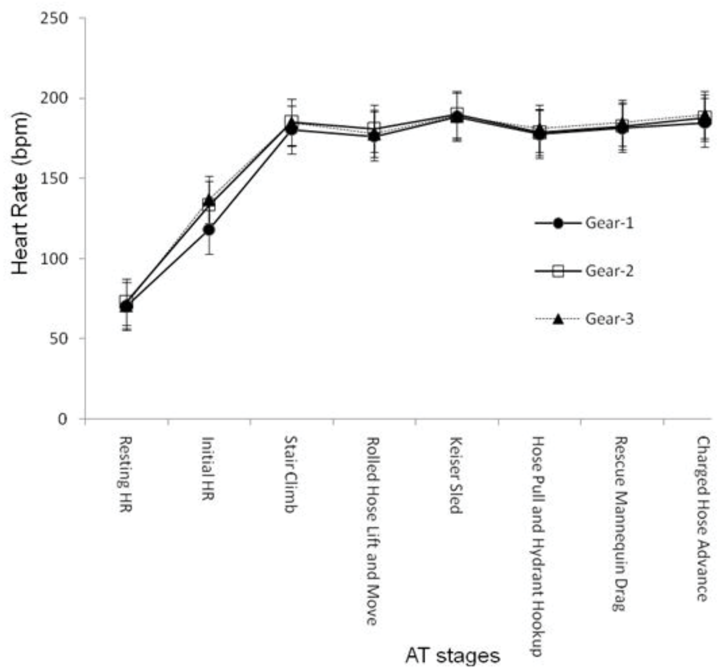

Figure 1 HR responses of the three gear group

HR kinetics throughout the AT appeared to be identical among the three different groups. The univariate test was in agreement with the multivariate results see **Table (8-9)**. There was a significant time effect Heart Rate (HR), ($F(7,329)=707.94$, $p<0.01$), but a no significant time gear interaction effect, ($F(14,329)=1.67$, $p=0.69$).

Figure 1: Table 7: Repeated measures analysis of variance-summary table for investigation of changes in heart rate over the AT test.

Source	df	SS	MS	F	p
Gear	2	1963.66	981.83	1.53	0.22
Error B/W	47	30129.9	641		
Note: MS:Mean Square, SS:Sum of Squares					

Table 8: Univariate tests of hypotheses for within-subject effects.

Source	df	SS	MS	F	p
Hr	7	521035.9	74.433.69	707.94	< .01
Hr *Gear	14	2399.46	171.39	1.63	0.07
Error (time)	329	34591.24	105.14		
Note: MS: Mean Square, SS:Sum of Squares, HR:Heart Rate.					

Table 9: The average hr responses during the stages concerning gear.

Variable	Vest		Gear		Gear (air)	
	M	SD	M	SD	M	SD
Resting HR (bpm)	71	11	74	11	69	15
Initial HR (bpm)	121	25	136	21	133	23
Stair Climb (bpm)	181	14	185	8	185	11
Rolled Hose Lift and Move (bpm)	175	11	181	10	178	14
Keiser Sled (bpm)	189	9	190	10	188	10
Hose Pull and Hydrant Hookup (bpm)	177	10	179	10	180	14
Rescue Mannequin Drag (bpm)	181	8	183	9	183	13
Charged Hose Advance (bpm)	184	8	188	9	188	12
Note: BPM: Beats Per Minute, HR:Heart Rate. The Gear and Gear (air) groups were in full turnout gears. The Gear (air) group had the positive pressure mask on and used the SCBA to breath.						

Discussion

It has been suggested that the adverse effects of gear on firefighting performance could be due to the extra weight carried [27], the material of the protective clothing [12], the weight distribution [28], the breathing resistance of the regulators used with SCBA [27] or a combination of these factors. This study examined the effects of protective gear, SCBA, and weight vest on simulated firefighting performance. The weight vest was selected to remove the discomfort of the respirator and protective clothing but maintain the effect of the extra weight. The results of this study indicated that there was a significant effect of firefighters' HR over time (stages of the AT). Heart rate significantly increased from rest to anticipation phase in all three groups with no exercise stimulus. The increase in HR was probably due to sympathetic nerve activation resulting from the anticipation of the "start" signal as well as the extra weight. The average HR of the gear-1 group just before the "start" signal was 121 (bpm) compared to the averages of 136 bpm and 133 bpm recorded in the gear-2 and gear-3 groups, respectively. Although the difference was too small to be statistically significant, the higher HR in groups (2-3) could be attributed to the body heat produced by the protective clothing [29]. Nevertheless, the HR in all three groups increased rapidly from the rest to the preparation phase. A similar response to the anticipation phase was previously observed during actual fire alarms [30], where HR responses were indicated to increase by an average of 47 bpm, 30secs after the alarm and reported to be as high as 150 bpm just before firefighters got off the truck to initiate firefighting tasks. During the anticipation phase, the HR in this study was recorded as high as 175 bpm, and the average HR of all firefighters in all three groups was 128 bpm. Furthermore, research [30] indicated that firefighters exhibited HRs that ranged from 150 bpm-190 bpm for an extended period during actual firefighting. In this study, the average HR response while performing the simulated firefighting tasks ranged from 159 bpm-198 bpm. These results indicated that firefighters in the current study experienced augmented internal load similar to that observed during actual firefighting [30]. The results of the current study demonstrated that during the test, the HR kinetics appeared to have a similar trend for all gear groups. The average HR (183 bpm) for all three groups measured at the end of the stair climb task (task 1) was 99.39% of the age-predicted max. The firefighters exhibited HR values close to their age-predicted HR max despite that stair climb was the first task of the test. In agreement were the results of Smith et al. (2001) [18], who reported that the mean HR increased quickly during trial-1 (175 bpm) and then reached age-predicted maximum HR during trial-3. Heart rate was also demonstrated to be highly elevated (93%-97% of maximal HR) in firefighters performing a modified combat task test consisting of stair climbing, chopping simulation, and victim rescue simulation [23]. Louhevaara et al. (1995) [31] suggested that maximal physical work performance in firefighters decreased due to the protective gear and that the reduced work output was related to the increased weight (25.9 kg). On the contrary, Manning and Griggs (1983) [32] demonstrated no significant difference in the exertion levels among the three experimental SCBA (no SCBA, light SCBA, and heavy SCBA) conditions in which the weight carried was the variable of interest. In addition, Griefahn et al. (2003) [28] suggested that the weight of the SCBA might not influence job performance, but the SCBA's weight distribution might have an impact on firefighting performance. The investigators indicated that firefighters with an innovative rucksack shape of 13.7 kg SCBA provided a better distribution of the weight over the middle and lower parts of the back. Furthermore, the firefighters with the particular SCBA exhibited faster completion times, lower HR and RPEs than conventional SCBA that weighted less. The current study contradicts the findings of Griefahn et al. since the weight of the gear and not the distribution in all three conditions was enough to elicit a high internal load similar to the internal load observed during actual firefighting [30]. This study demonstrated that performing firefighting tasks could be a very physically demanding job even when the tasks are performed under ambient conditions without live fires and the sense of immediate danger. The strenuous nature of the AT was evident by the exertion levels measured as a function of HR increase relative to the maximum predicted HR. The average HR during the tasks was 182 bpm ± 9 bpm, which was calculated to be 99.08% ± 4.71% of the age estimated HR max (184 bpm ± 5 bpm). The highest average HR (189 bpm) appeared to be at the end of the Keiser sled, which was 102.72% of the age-predicted max. The average HR at the end of the test was 101.08 % of the age-predicted max. Similar to the HR responses, all three gear conditions have exhibited high lactate values and RPE. Upon completing the AT, firefighters reported an average RPE of 14.93 ± 1.48, where 15 represents "hard" on the Borg scale (Borg, 1998). Eglin and Tipton (2005) [33] also demonstrated high RPE (16.3 ± 2.4) values among firefighter instructors who performed a simulated rescue task after undertaking a 40-min live-fire training exercise. In addition, lactate levels increased about 13-fold 12.98 mmol/l ± 2.36 mmol/l four minutes after the test. Lactate accumulation was significantly inversely correlated with AT time ($r=-0.30$, $p<0.05$), indicating that those who completed the AT faster exhibited higher lactate values. Accordingly, it shows that firefighters who performed better on the test exerted greater effort. These results were in line with Gledhill and Jamnik [34], who demonstrated lactate values that ranged from 6 mmol/l-13.2 mmol/l from samples obtained five minutes after the completion of essential firefighting tasks. Similarly, von Heimburg et al. (2006) [24] reported a lactate concentration of 13 mmol/l ± 3 mmol/l after a simulated rescue of hospital patients. Even higher than the aforementioned lactate accumulations were reported by Petersen et al. (2000) [35] after a job-related task (hose carry, stair climb, victim rescue simulations, and rope pull forcible entry) during normoxic and hyperoxic conditions (15.57 and 15.74 mmol/l, respectively). The significant contribution of the anaerobic energy system during firefighting is evident by the blood lactate levels demonstrated on firefighters in the aforementioned studies and the results of this study. The required energy demand exceeds the aerobic capacity, and a significant fraction of ATP derives from anaerobic metabolism. This type of activity (all-out efforts) is usually dependent initially on the glycolytic pathway that would elicit high levels of intracellular accumulation of inorganic acids, out of which lactic acid is the most important [36]. Identifying how gear variations or the use of weight vests during firefighting ability testing affect the firefighters' performance could be necessary to administrators. The reason is that simulated firefighting tests are used to evaluate new recruits and active firefighters. It should be noted that the results of this study are limited to experienced firefighters who are familiar with the use of the protective outfit and SCBA. Thus, the use of full gear and SCBA to test inexperienced potential recruits could have a different outcome and requires further investigation. This study is essential since the test was administered to all the firefighters as part of their annual assessment, which is not common in similar studies as

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participation is done on a voluntary basis. Therefore, this is one of the few studies that contextualized firefighters' internal load during simulated firefighting events by limiting participation bias.

Conclusion

Based on the results of this study, it is evident that firefighting can be as strenuous with a weight vest as with full turnout gear and SCBA. Therefore, a vest with the same weight as the complete protective outfit and SCBA could be used effectively to simulate gear during simulated firefighting under ambient conditions. In addition, the weight vest could be a valuable training tool for potential firefighters who are preparing for a physical candidacy exam. The strenuous nature of the simulating firefighting test and its tasks is evident by the blood lactate accumulation and the HR kinetics recorded throughout the tasks. The present study further supports the previous work of several investigators who demonstrated similar physiological responses to simulated and actual firefighting. These findings could be necessary to administrators since simulated firefighting tests evaluate active firefighters and are used as a recruiting tool for new firefighters.

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