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## Energy cost and energy sources during a simulated firefighting activity.

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# UNIVERSITÀ DEGLI STUDI DI TORINO

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## Abstract

Perroni, F, Tessitore, A, Cortis, C, Lupo, C, D'Artibale, E, Cignitti, L, and Capranica, L. Energy cost and energy sources during a simulated firefighting activity. *J Strength Cond Res* 24(12): 3457-3463, 2010-This study aimed to 1) analyze the energy requirement ( $\dot{V}O_{2eq}$ ) and the contribution of the aerobic ( $\dot{V}O_{2ex}$ ), anaerobic alactic ( $\dot{V}O_{2al}$ ), and anaerobic lactic ( $\dot{V}O_{2la-}$ ) energy sources of a simulated intervention; 2) ascertain differences in mean  $\dot{V}O_2$  and heart rate (HR) during firefighting tasks; and 3) verify the relationship between time of job completion and the fitness level of firefighters. Twenty Italian firefighters (age =  $32 \pm 6$  yr,  $\dot{V}O_{2peak} = 43.1 \pm 4.9$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) performed 4 consecutive tasks (i.e., child rescue; 250-m run; find an exit; 250-m run) that required a  $\dot{V}O_{2eq}$  of  $406.26 \pm 73.91$  mL·kg<sup>-1</sup> ( $\dot{V}O_{2ex} = 86 \pm 5\%$ ;  $\dot{V}O_{2al} = 9 \pm 3\%$ ;  $\dot{V}O_{2la-} = 5 \pm 3\%$ ). After 30 minutes, the recovery HR ( $108 \pm 15$  beats·min<sup>-1</sup>) and  $\dot{V}O_2$  ( $8.86 \pm 2.67$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) were higher ( $p < 0.0001$ ) than basal values (HR =  $66 \pm 8$  beats·min<sup>-1</sup>;  $\dot{V}O_2 = 4.57 \pm 1.07$  mL·kg<sup>-1</sup>·min<sup>-1</sup>), indicating that passive recovery is insufficient in reducing the cardiovascular and thermoregulatory strain of the previous workload. Differences ( $p < 0.001$ ) between tasks emerged for mean  $\dot{V}O_2$  and HR, with a lack of significant correlation between the time of job completion and the firefighters' aerobic fitness. These findings indicate that unpredictable working conditions highly challenge expert firefighters who need adequate fitness levels to meet the requirements of their work. Practically, to enhance the fitness level of firefighters, specific interval training programs should include a wide variety of tasks requiring different intensities and decision-making strategies.

## Introduction

Firefighting is one of the most physically demanding and hazardous of all civilian occupations (8,24). The demands of firefighting depend on the variable and unpredictable working conditions that pose heavy physical and mental stress on firefighters (8,21). Heart rates (HR) ranging 84-100% of individual's maximum, corresponding to 63-97% of estimated maximum oxygen uptake ( $\dot{V}O_{2max}$ ), have been reported during actual emergencies (41). The severe physiologic stress has been attributed to the combined effect of the metabolically active muscles to support heavy muscular work (4,41) and the thermoregulatory strain (1,6,25,28,29,36-40) resulting from the heavy, isolative, nonpermeable protective gear (i.e., gloves, boots, Nomex flash hood, helmet) and a self-contained breathing apparatus (SCBA), which proved to determine a 25% increase in energy expenditure (27) and 22% and 75% reductions of tolerance time running at low and high working intensities, respectively (44). Thus, the high-energetic work of firefighting might cause fatigue, over-exhaustion, and impaired cognitive function, which may compromise firefighters' and victims' health and safety (17,25,36,46).

Given the limited availability of firefighters to take part in experimental settings during real interventions, the physical demands and psychological distress of firefighters have been investigated mainly in laboratory (9,13,28,42), whereas few studies have made use of experimental settings simulating firefighting interventions (4,16,22,43,45). Firefighting being an open-skill activity highly influenced by unpredictable environmental conditions, time for completion of firefighting interventions might depend on the firefighter's fitness and experience

levels, the relative strain on the firefighter depending on the aerobic and anaerobic requirements of the job, or a combination of these aspects (10). A few studies reported the oxygen consumption to estimate energy expenditure during simulated firefighting tasks performed wearing the SCBA (16,22,23,26,35), but the interpretation of findings is difficult when based on data registered in laboratory conditions with subjects wearing light gym clothes. Despite the fact that anaerobic metabolism during firefighting interventions have been reported (4,22,43), caution should be used in situations where lactic and alactic anaerobic metabolisms may play a different role. Furthermore, firefighting tasks might vary in requirements ranging from highly physical closed skills to more complex skills with high cognitive components that highlight the potential contributory factors of expert cognition, such as attentional and planning strategies.

Although a relationship between firefighting task demands and the fitness level of the firefighters could be hypothesized, no study has addressed this issue. Thus, the aims of the present study were 1) to analyze the energy requirement and the contribution of the aerobic and anaerobic energy sources during a simulated intervention; 2) to ascertain differences in mean  $\dot{V}O_2$  and HR during closed and open skill firefighting tasks; and 3) to verify the relationship between time of job completion and the fitness level of the firefighters.

## Methods

### Experimental Approach to the Problem

The institutional review board for use of human subjects approved the study. The cooperation of the Italian Fire Fighting Corp gave us the opportunity to have access to physiologic measurements of firefighters in a simulated setting. Professional firefighters were recruited to execute a job-related performance test. The participants engaged in 2 experimental sessions organized during the first 2 weeks of November 2007. The first session included anthropometric (i.e., height, body mass) and  $\dot{V}O_{2max}$  measurements. The second session aimed at evaluating the energy cost of a simulated firefighting rescue intervention using a portable metabolimeter (K4b2, Cosmed, Rome, Italy). Because firefighters do not perform tasks in a specific sequence, in line with the opinion of 3 fire instructors, 4 tasks were included in the simulated intervention to be completed as quickly as possible: a) climb a firemen's ladder and descend a 3-floor building carrying a 20 kg child dummy (child rescue); 2) run for 250 m; 3) complete a maze in a dark chamber (find an exit); and 4) run for 250 m. The 250-m runs were selected to represent activities with high physical and low cognitive demands (i.e., closed skills). The child rescue and the find an exit were selected to represent activities requiring high cognitive demands performed under time pressure (i.e., open skills). No smoke or heat was used in this study to prevent damage to the portable metabolimeter.

The contribution of the 3 energy sources to the overall energy requirement of the simulated firefighting intervention ( $\dot{V}O_{2eq}$ ) was calculated according to the literature (3,11) from  $\dot{V}O_2$  and blood lactate concentration ([La]) data. In particular, the amount of  $\dot{V}O_2$  above resting ( $\dot{V}O_{2ex}$ ) collected during the exercise and the first 10 seconds of the recovery phase was attributed to the aerobic source. The anaerobic alactic source ( $\dot{V}O_{2al}$ ) was estimated from the  $\dot{V}O_2$  fast component of the recovery phase by applying a nonlinear least-squares fitting procedure (30). The anaerobic lactic

source ( $\dot{V}O_{2a}$ ) was calculated by multiplying the net increase (i.e., peak resting values) of  $[La]$  by the  $O_2$  equivalent ( $3 \text{ mL} \cdot O_2 \cdot \text{kg}^{-1}$ ) (12,19).

To identify the beginning and the end of the different tasks of the simulated intervention, an experimenter pressed the marker button of the metabolimeter. Thus, it was hypothesized that the closed- (i.e., 250-m runs) and open-skill (i.e., child rescue and find an exit) tasks would differ for mean  $\dot{V}O_2$ . Finally, a relationship between the fitness level of the firefighters and the time to job completion was expected.

## Subjects

Before the investigation, information of the experimental procedures and potential risks of this study was provided to 20 male professional Italian firefighters (age:  $32 \pm 6$  yr) who signed an informed consent. The American Alliance for Health, Physical Education, Recreation and Dance exercise/medical history questionnaire was used to ascertain the firefighters' activity level, educational background, dietary habits, tobacco smoking and alcohol consumption, medication use, and history of physical activity. The firefighters had at least 3 years of previous firefighting experience and were not engaged in structured physical training programs.

## Procedures

All the tests were performed with participants wearing their own complete National Fire Protection Agency standard protective firefighting garments to allow comparisons between laboratory and field data (1). Beneath the protective garments, the firefighters wore underwear, socks, standard issue cotton station long pants, and a cotton t-shirt. The total weight of the ensemble was approximately 23 kg.

## Laboratory Evaluation

The firefighters reported to the laboratory (ambient temperature:  $21 \pm 2^\circ\text{C}$ ; relative humidity:  $55 \pm 5\%$ ) to perform a graded incremental treadmill test to exhaustion (RunRace HC 1200, Technogym, Gambettola, Italy) wearing their SCBA. During the test, HR (Sport Tester, Polar Electro, Kempele, Finland),  $[La]$  (Accusport Lactate Analyser, Roche, Basel, Switzerland),  $\dot{V}O_2$ , carbon dioxide production ( $\dot{V}CO_2$ ), and ventilation were measured (K4b2, Cosmed, Rome, Italy), and expiratory rate ratio was calculated. The K4b2 data showed intraclass reliability coefficients ranging from 0.7 to 0.9 (14). The flow meter was calibrated with a 3 L syringe (Hans Rudolph, Inc., Dallas, TX, USA), and the gas analyzer was calibrated with known gas mixtures ( $O_2$ : 16.0% and 20.9%;  $CO_2$ : 5.0% and 0.03%). Before the test, a 5-minute warm-up of walking at  $6 \text{ km} \cdot \text{h}^{-1}$  with a 0% of slope was performed. This  $\dot{V}O_{2\text{max}}$  test consisted of 3-minute stages starting at a treadmill speed of  $8 \text{ km} \cdot \text{h}^{-1}$  followed by a  $2 \text{ km} \cdot \text{h}^{-1}$  increase in treadmill speed every 3 minutes until the participant reached volitional exhaustion. Then, a 5-minute active recovery was given with walking at  $5 \text{ km} \cdot \text{h}^{-1}$  at 0% slope. The  $\dot{V}O_{2\text{max}}$  was identified at the occurrence of a plateau or an increase less than  $1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  of  $\dot{V}O_2$  despite further increases in the exercise intensity, a respiratory gas exchange ratio higher than 1.15,  $[La]$  higher

than 9 mM, and an HR  $\pm$  5 beats·min<sup>-1</sup> of predicted HR<sub>max</sub> (220 - age). When the test ended before the attainment of the  $\dot{V}O_{2\max}$ , peak oxygen consumption ( $\dot{V}O_{2\text{peak}}$ ) was calculated by averaging the final 30-second values of the exercise test.

### Data Collection During Simulated Firefighting Intervention

Firefighters reported to the firefighting training center at 8:00 am (ambient temperature:  $13 \pm 1^\circ\text{C}$ ; relative humidity:  $63 \pm 1\%$ ) to have their basal measurements collected. During the simulated firefighting intervention, HR was continuously recorded (Team System, Polar, Kempele, Finland) as average values of 5 seconds.

The K4b2 flow meter was positioned on the SCBA to minimize interference with task performance. Ventilatory gases were collected from 5 minutes before to 25 minutes after the end of the simulated firefighting intervention and recorded as averaged values every 5 seconds. Then, average values were calculated for each task. The [La] in finger capillary blood was measured (Accutrend Lactate, Roche, Basel, Switzerland) before and at 3, 6, and 9 minutes after the end of the test with a 0.992 single-trial intraclass reliability (5).

### Statistical Analyses

A 0.05 level of confidence was selected for this study. Because the 4 firefighting tasks of the simulated intervention vary in duration, a 2 (skill)  $\times$  2 (task) analysis of variance for repeated measures was applied to test differences only in mean  $\dot{V}O_2$  and HR values. If the overall F-test was significant, post hoc Fisher protected least significant difference comparisons were used, and Cohen's effect sizes (ES) were calculated, considering values 0.2 or less trivial, from 0.3 to 0.6 small, less than 1.2 moderate, and greater than 1.2 large. The individual's  $\dot{V}O_{2\max}$  was correlated to the time required to complete the 4 firefighting tasks and the whole intervention.

### Results

Anthropometric characteristics of the firefighters were height  $177 \pm 6$  cm; body mass  $77.2 \pm 8.7$  kg; and body mass index  $24.7 \pm 2.1$ . During the incremental treadmill test performed with the SCBA, it was not possible to assume that the firefighters reached their  $\dot{V}O_{2\max}$  given the absence of a  $\dot{V}O_2$  plateau, HR<sub>max</sub> values corresponding to  $90 \pm 5\%$  ( $176 \pm 9$  beats·min<sup>-1</sup>) of their theoretical HR<sub>max</sub>, and peak [La] values of  $8.8 \pm 2.0$  mM. Thus,  $\dot{V}O_{2\text{peak}}$  was  $43.1 \pm 4.9$  mL·kg<sup>-1</sup>·min<sup>-1</sup>.

The  $\dot{V}O_2$  increased abruptly at the beginning of the intervention, fluctuated during the execution of the different tasks, decreased rapidly at the end of the intervention, and continued to decline smoothly during the slow recovery phase (Figure 1). To complete the simulated intervention, a  $\dot{V}O_{2\text{ex}}$  of  $351.10 \pm 72.8$  mL·kg<sup>-1</sup> (child rescue:  $40.9 \pm 14.2$  mL·kg<sup>-1</sup>; first 250 m:  $57.8 \pm 16.9$  mL·kg<sup>-1</sup>; find an exit:  $198.6 \pm$

51.4; second 250 m:  $53.8 \pm 17.2$ ) was required. At the end of the simulated intervention, [La] peak values ( $9.2 \pm 2.9$  mM) were often observed between 3 (frequency of occurrence = 57%) and 6 minutes (frequency of occurrence = 33%) of the recovery phase. Table 1 reports the contribution of the different sources to the total exercise cost ( $\dot{V}O_{2eq} = 406.26 \pm 73.91$  mL·kg<sup>-1</sup>). The highest fraction ( $86 \pm 4\%$ ) was represented by the aerobic source, whereas the anaerobic fraction represented approximately 14%. The metabolic power requirement expressed per minute (i.e.,  $\dot{V}O_{2eq}$ ) was  $35.51 \pm 6.5$  mL·kg<sup>-1</sup>·min<sup>-1</sup>, corresponding to approximately  $80 \pm 15\%$  of the subject's  $\dot{V}O_{2peak}$ . After 30 minutes of recovery, differences in HR ( $F(2, 38) = 631.24$ ,  $p < 0.0001$ ) and  $\dot{V}O_2$  ( $F(1, 19) = 112.64$ ,  $p < 0.0001$ ) were still present, with higher postexercise values (HR:  $108 \pm 15$  beats·min<sup>-1</sup>;  $\dot{V}O_2$ :  $8.86 \pm 2.67$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) with respect to basal values (HR:  $66 \pm 8$  beats·min<sup>-1</sup>;  $\dot{V}O_2$ :  $4.57 \pm 1.07$  mL·kg<sup>-1</sup>·min<sup>-1</sup>).

	$\dot{V}O_2$ (mL·kg <sup>-1</sup> )	% $\dot{V}O_{2eq}$
$\dot{V}O_{2ex}$	$351.10 \pm 72.77$	$86 \pm 5$
$\dot{V}O_{2al}$	$35.69 \pm 9.16$	$9 \pm 3$
$\dot{V}O_{2la-}$	$19.47 \pm 8.83$	$5 \pm 3$
$\dot{V}O_{2eq}$	$406.26 \pm 73.91$	—

Table 1. Means  $\pm$  standard deviations of the contribution of aerobic ( $\dot{V}O_{2ex}$ ), alactic ( $\dot{V}O_{2al}$ ) and lactate ( $\dot{V}O_{2la-}$ ) sources to the overall energy cost ( $\dot{V}O_{2eq}$ ) of the firefighting intervention.

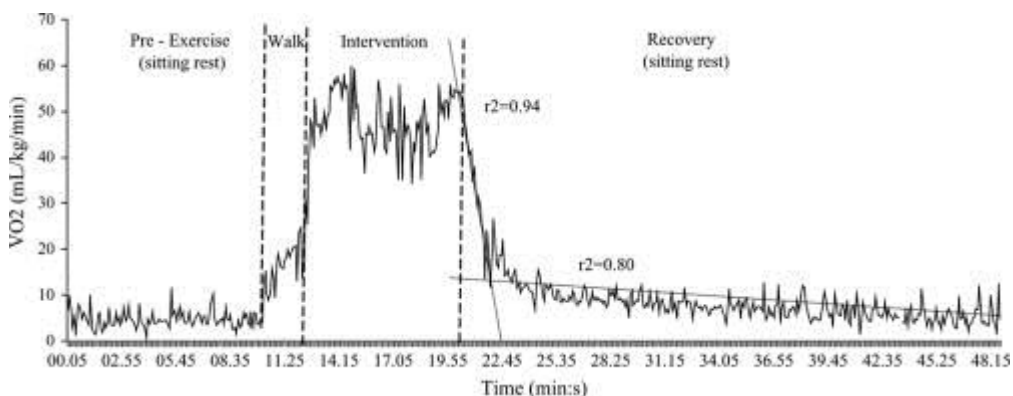


Figure 1. Individual values of oxygen consumption ( $\dot{V}O_2$ ) curve before (sitting rest and walking to start line), during, and after (fast and slow recovery) firefighting simulated intervention. Dotted lines represent regression relative to fast and slow recovery phases of  $\dot{V}O_2$ .

Table 2 shows the means and SDs of HR, ventilatory parameters, and time to job completion recorded during each firefighting task. Firefighters used  $704 \pm 135$  seconds to complete the intervention, being fastest when they had to climb a firemen's ladder and descend the 3-floor building carrying a 20 kg child dummy ( $82 \pm 25$  s) and slowest when they had to find an exit in the dark chamber ( $438 \pm 117$  s). The HR increased at the beginning of the intervention and tended to remain elevated until its end (Figure 2), with the highest frequency (80%) of HRpeak ( $184 \pm 9$  beats·min<sup>-1</sup>) observed during the last 250-m run. Mean HR showed main effects for skill ( $F(1,19) =$

23.7,  $p < 0.0001$ ), type ( $F(1,19) = 8.1, p = 0.0104$ ), and their interaction ( $F(1,19) = 18.9, p = 0.0003$ ). Post hoc analysis maintained differences only between HR recorded during the child rescue and the other tasks (ES ranging from 0.52-0.57).

Tasks	Dependent Variables				
	HR (beats·min <sup>-1</sup> )	% HR <sub>peak</sub>	$\dot{V}O_2$ (mL·kg <sup>-1</sup> ·min <sup>-1</sup> )	% $\dot{V}O_{2peak}$	Time (s)
Child Rescue	145 ± 21*	77 ± 11	29.38 ± 6.83	70 ± 18	81.8 ± 25.3
250-m Run 1	166 ± 9	88 ± 5	38.49 ± 6.53†‡	90 ± 14	92.8 ± 24.6
Find an Exit	165 ± 10	88 ± 6	28.23 ± 6.80	67 ± 16	437.5 ± 116.6
250-m Run 2	170 ± 14	91 ± 8	34.87 ± 7.13†	82 ± 17	91.5 ± 23.7

\* $p < 0.0001$  with respect to the other tasks  
† $p < 0.0001$  with respect to child rescue and find an exit tasks  
‡ $p = 0.008$  with respect to the 250 m Run 2 task

Table 2. Means ± standard deviations of the average values for heart rate (HR), oxygen consumption ( $\dot{V}O_2$ ), and time recorded during the four firefighting tasks of the simulated intervention performed by the Italian firefighters ( $n=20$ ).

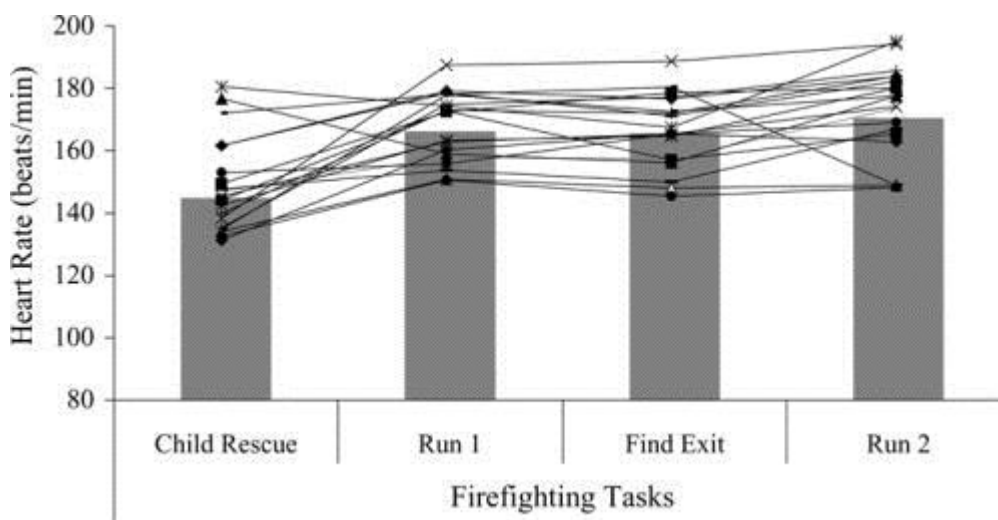


Figure 2. Group means and individual mean heart rates recorded during firefighting tasks.

During exercise, highest  $\dot{V}O_2$  values and interindividual differences were observed when firefighters performed the find an exit task (Figure 3). Mean  $\dot{V}O_2$  showed a main effect only for skill ( $F(1,19) = 137.6, p < 0.0001$ ), with higher values recorded during closed skills (i.e., running:  $36.6 \pm 7.0$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) with respect to open skills (i.e., child rescue and find an exit:  $28.8 \pm 6.7$  mL·kg<sup>-1</sup>·min<sup>-1</sup>).

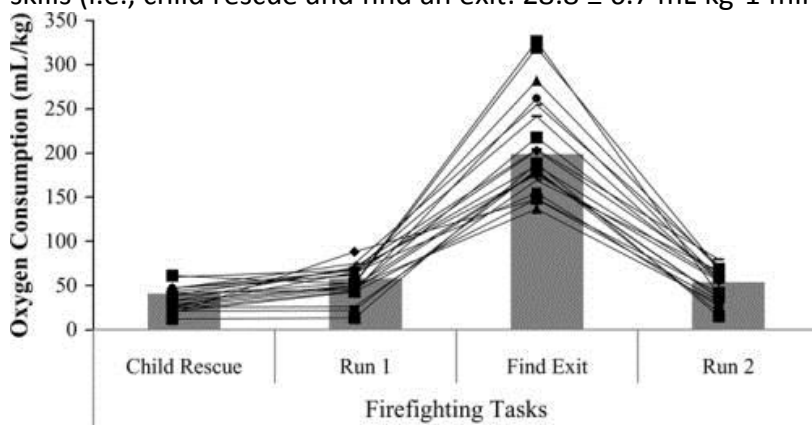


Figure 3. Group means and individual mean oxygen consumptions recorded during firefighting tasks.



A correlation coefficient of 0.09 ( $p = 0.72$ ) was found between  $\dot{V}O_{2\text{peak}}$  recorded during the treadmill test and time to job completion of the simulated intervention. Furthermore, correlation coefficients ranging from 0.09 to 0.53 emerged between  $\dot{V}O_{2\text{peak}}$  and time to complete the different tasks.

## Discussion

During rescue interventions, Italian firefighters usually perform multiple tasks depending on the situation, unless specific abilities are required (i.e., diving, handling chemicals, etc.). Firefighting activities such as victim search and rescue, ladder climbing, and carrying victims are proven to require a high-energy expenditure (7,15,21,43). However, there is a lack of information regarding the specific contribution of the 3 energy sources involved in rescue interventions. Furthermore, the relative intensities of firefighting might be underestimated when the physiologic responses of activities performed with the protective SCBA are related to laboratory tests performed with light clothes. In fact, the combined effects of an intense working activity and the addition of heavy, thick, multilayered, and bulky self-protecting clothing generate increases in thermoregulatory and cardiovascular strain, augment energy expenditure, and reduce working tolerance (2,27,34). Thus, in this study, the firefighters were always tested wearing their own fire garments to better determine the contribution of the aerobic and anaerobic metabolisms to the energy requirement of a simulated firefighting intervention and thus to ascertain differences in mean  $\dot{V}O_2$  and HR during firefighting tasks with different physical and cognitive demands and to verify whether a relationship exists between time of job completion and the fitness level of the firefighters. The main findings of this study were 1) the studied intervention posed high demands on the firefighters, sustained mainly by the aerobic metabolism; 2) closed and open skill tasks differ for mean  $\dot{V}O_2$  and HR; and 3) there is no relationship between time of job completion and the fitness level of the firefighters.

In measuring the aerobic power of firefighters in laboratory conditions wearing light clothes, some authors indicated a minimum level of  $45 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$   $\dot{V}O_{2\text{max}}$  to successfully complete intense firefighting tasks (7,21,41). Despite the participants of this study having declared not to be involved in any additional physical training, they showed a high aerobic fitness. In fact, during the treadmill test wearing the SCBA, the firefighters showed a  $\dot{V}O_{2\text{peak}}$  of  $43 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , corresponding to  $55 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  without protective garments (31).

As expected, the simulated interventions were highly demanding (4,23,43), with peak HR,  $\dot{V}O_2$ , and [La] values corresponding to 97%, 80%, and 105% of those recorded during the treadmill test, respectively. Relative to the contribution of the 3 energy sources, the aerobic system was the most used (86%), whereas 14% was attributable to anaerobic sources (i.e., alactic 9%, lactic 5%). These results might be a result of the duration (i.e., 12 min) and the good fitness level of the firefighters, who paced themselves during the intervention. However, in line with previous studies (16,43), high [La] (approximately 9 mM) was observed at the end of the intervention, and HRs remained elevated (approximately  $110 \text{ beats}\cdot\text{min}^{-1}$ ) after 30 minutes postintervention. These findings indicate that the passive recovery was insufficient in reducing the

cardiovascular and thermoregulatory strain of the previous workload. To accelerate the physiologic recovery after bouts of intense firefighting activities, a cooling strategy is recommended (2).

In this study, job demands varied between tasks, with the highest metabolic load observed during running. Considering that firefighters usually run when are impelled to rescue a victim or when unpredictable environmental conditions urge them to escape from a dangerous site, these results highlight the necessity to train their speed and agility capabilities in addition to their aerobic capacity (18). On the other hand, the HR responses increased from the first task (i.e., climb a firemen's ladder and descend a 3-floor building rescuing a 20 kg child dummy) and remained elevated even when firefighters mostly walked to complete a maze to find an exit in a dark room. The high HR and the fairly low  $\dot{V}O_2$  data recorded in this condition substantiate the idea that working in unpredictable environmental conditions poses a high stress on firefighters, especially under thermoregulatory strain.

Time for firefighting job completion has been hypothesized to depend on fitness level, years of practice, and familiarity (22,23,43), although conflicting results emerge in relation to methodologic differences caused by the specificity of the studied tasks. In fact, successful performance depends on several factors (i.e., environmental condition, experience and skill, fitness and work rate, duration, and psychological stress) so that a high interindividual variability might be expected. In this study, the highest variability in task completion was found when firefighters had to complete a maze to find an exit in a dark room (range: 5-11 min). More than exercise demands, this particular task implies a high skill level in orienting in the dark and encountering unknown obstacles (i.e., moving floors, gates, ceiling at various heights, etc.). Therefore, the lack of significant correlation between the time of job completion and the firefighters' aerobic fitness indicates that unpredictable working conditions highly challenge expert firefighters. In light of these findings, it could be advisable to include job-related tasks of different difficulty levels in training programs for firefighters.

Considering that the firefighters involved in this study were young adults (range 24-41 years), it is conceivable that in future years the expected age-related physiologic decrements (42) will expose them, their coworkers, and victims to high risk. Despite the fact that in Italy the expected retirement age for firefighters is approximately 60 years, the Italian Firefighting Corp does not organize structured training programs or administer yearly evaluations to verify that firefighters meet minimal performance standards necessary to accomplish efficient working activity during their occupational period. On the other hand, a better working capacity could result through introduction of structured training (23,32,33). In conclusion, these findings strongly support the need of sound training programs for Italian firefighters, who might be more likely to be involved in regular exercise on duty when proper time during the shift is scheduled and onsite fitness facilities are available (20).

## Practical Applications

By providing information on the involvement of metabolic sources during a firefighting intervention, the present findings substantiate the need for specific interval training programs for firefighters that aim at increasing their aerobic and anaerobic performances. Furthermore, considering that a high situational unpredictability characterizes firefighting activities, an integrated approach to training is necessary, which includes a wide variety of tasks requiring different intensities and decision-making strategies. Furthermore, considering that firefighters perform their job wearing protective clothing, it is strongly recommended that the fitness tests be performed in this condition. Finally, to prevent age-related decline of physiologic functions and to avoid the risks of job-related injuries, the Italian Firefighting Corp should introduce screening programs to ensure that physically capable personnel perform this crucial public safety job. Although the advent of emergencies are a barrier to organized conditioning sessions when firefighters are on duty, to ensure that they adhere to job-related exercise programs, Italian Firefighting Departments are urged to provide training facilities and to employ health and fitness experts who could individualize the content and periodization of training.

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