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The Influence of Age on Aerobic Capacity and Health Indicators of Three Rescue Groups

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The aim of this study was to determine the relationship between age, aerobic capacity ($V_{O2\,max}$) and other health indicators among 3 rescue groups. The type of training and the subjective perception of physical fitness obtained via the Assessment Questionnaire of Physical Fitness were also analysed. To obtain $V_{O2\,max}$, 37 firefighters, 22 lifeguards and 59 mine rescue workers had a treadmill test. Their body mass index and body fat percentage were also calculated. The results show a significant decline in $V_{O2\,max}$ of the older participants, which affects the effectiveness of rescue work. Furthermore, the training of all groups was inconsistent and based on individual needs. Variable training and the decline in $V_{O2\,max}$ with age affected the effectiveness of the rescue tasks of each group.

physical aptitude fitness $V_{O2\,max}$ body mass index rescue groups

1. INTRODUCTION

Aerobic capacity ($V_{O2\,max}$) is an essential element of physical training of professionals who work at maximum effort levels when undertaking rescue tasks [1]. $V_{O2\,max}$ plays an important role in both long and short interventions; in the former as the main source of energy and in the latter as a factor maintaining fitness levels and shortening lactate and oxygen recovery time.

According to various studies, $V_{O2\,max}$ is the most appropriate criterion for assessing physical fitness of rescue groups such as firefighters [2, 3, 4, 5]. It is also a leading indicator when implementing training programme for improving the cardiorespiratory fitness of different groups [6, 7, 8].

Other studies show that proper training can increase $V_{O2\,max}$ of rescue groups by over 20% [9, 10, 11]. This fact is important for professions in which the intensity of actions and the demand for energy levels and muscular activity do not decrease with age. Lusa, Louhevaara and Kinnunen stated that physical work and the demand for working capacity remains the same throughout a firefighter's career [12]. Bugajska, Zużewicz, Szmauz-Dybko, et al. confirmed this [13]. Rescue tasks performed by firefighters, mine rescue workers and lifeguards require similar levels of $V_{O2\,max}$ [2, 14, 15].

Even though $V_{O2\,max}$ is a criterion for assessing physical fitness of rescue groups, their training should include exercises based on strength, speed and flexibility [16]. According to some studies, firefighters' health is not as good as it ought to be, possibly because of the lack of proper training [17, 18]. A perception error of over-rating $V_{O2\,max}$ could result in an inability to meet the physical demands of rescue groups [19, 20, 21].

Body mass index (BMI) and body fat percentage are often used for assessing health levels of different population groups. According to Clark, Rene, Theurer, et al., these parameters are useful especially for firefighters [21]. Moreover, Soteriades, Hauser, Kawachi, et al. stated that neglecting

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training could cause an increase in BMI, which can later pose a risk to the health of members of rescue groups [22]. Riendeau, Welch, Crisp, et al. concluded that the degree of adiposity (not total body weight) is the factor that has a major influence on the performance of land-based tests [23].

The aim of this study was to determine the relationship between age, $V_{O2\,max}$ and other health indicators among three rescue groups. The type of training and the subjective perception of physical fitness obtained via the Assessment Questionnaire of Physical Fitness were analysed.

2. MATERIALS AND METHODS

2.1. Participants

Participants were randomly selected from a group of 358 firefighters, 281 lifeguards and 421 mine rescue workers. Participants could refuse to take part in the study. The size was estimated on the basis of a formula for calculating sample size for finite populations. Inclusion criteria for the study were (a) being a member of a rescue group for at least 2 years and (b) not taking a leave in the last 6 months because of illness or other situations that could alter current $V_{O2\,max}$. From the 139 subjects selected for the study, only 21 refused (attrition rate of 15.7%). All participants were male. Table 1 shows data on age, weight and height of the participants.

TABLE 1. Physical Parameters of the Participants

Rescue Group	Age (years)	Weight (kg)	Height (cm)
Lifeguards	21.4 ± 3.2	73.9 ± 9.9	175.7 ± 8.1
Firefighters	29.0 ± 3.6	74.7 ± 9.3	180.0 ± 3.2
Mine rescue workers	35.9 ± 4.8	82.3 ± 8.8	174.0 ± 5.5

2.2. Measurements

The examination of each group was identical and included an exercise test recording $V_{O2\,max}$. To obtain information on the physical activity, each participant filled out the Assessment Questionnaire of Physical Fitness [20].

The treadmill ergometer used in the exercise test was an LE 3-6 (Jaeger, Germany), with a precision rate of ±0.2 km/h, a speed range of 0.1–29.9 km/h and an incline range of 0–19.55%.

The Assessment Questionnaire of Physical Fitness had Likert items related to the participants' fitness and the type of activity or training. Participants graded their responses on a 0–7 scale. Some items referred to the participants' physical qualities and training.

BMI and body fat percentage were selected as health indicators for the rescue groups. BMI measures an individual's weight and height and is useful to identify firefighters' health levels [21]. Body fat percentage was measured with Faulkner's equation [24]:

$$\text{body fat percentage} = (\text{triceps} + \text{subscapular} + \text{suprailiac} + \text{abdominal skin} \times 0.153) + 5.783.$$

The measurements were done with a skinfold caliper (Holtain, UK) as recommended by the International Biological Programme.

2.3. Procedure

The participants were informed about the aim and protocol of the study. The tests were performed in the exercise physiology laboratory (area 57 m^2, height 4 m), between 9:00 and 12:00, for two consecutive weeks. Environmental conditions were maximized to obtain perfect ventilation and remained constant throughout the tests. The temperature was 20–22 °C and atmospheric pressure 720–750 mmHg. The Bruce treadmill test was used to record $V_{O2\,max}$ [25]. The test started with a speed of 2.7 km/h and an incline of 10%. The speed was progressively increased every 3 min by 1.3 km/h and the incline by 2%, until exhaustion. Breath samples were taken with a gas analyser (Sensormedics, USA) every 30 s.

2.4. Data Analysis

SPSS version 15 was used for data analysis. First, a descriptive analysis of all variables was performed. Student's *t* test for related samples, Spearman correlation test and Kolmogorov-Smirnov test to determine data normality followed. The association between the variables was established with a contingency test and a □^{2} statistical test.

The $V_{O2\,max}$ variable was divided into two groups creating actual aerobic capacity (AAC), a new dichotomic variable. The group which did not reach a minimum $V_{O2\,max}$ of 43 ml/min/kg (low AAC) was separated from the group with higher aerobic capacity (high AAC). Dichotomised AAC was used as a dependent variable. Two independent variables from the Assessment Questionnaire of Physical Fitness were used: the subjective assessment of training (SAT) in response to the question "Do you believe that your physical training matches the demands of your profession?" and the assessment of endurance (AE) in response to the item "Amount of time per week you spend on endurance training (aerobic)". Their aim was to determine the predictive value of the self-reported SAT and the AE to explain V_{O2}max; multivariate linear binary logistic regression was used. First, the SAT variable was used, then the AE.

3. RESULTS

The lifeguards' highest $V_{O2\,max}$ was 50.0 ± 11.3 ml/min/kg, the firefighters' 43.8 ± 9.4 ml/min/kg and the mine rescue workers' 36.0 ± 9.1 ml/min/kg.

There was a negative and statistically significant correlation between $V_{O2\,max}$ and the participants' age ($p < .001$) (Spearman test). In the three rescue groups, younger participants had greater $V_{O2\,max}$, while older ones had the lowest $V_{O2\,max}$ ($r_s = -.92$; $p = .001$) (Table 2).

The lifeguards's BMI was 24.1 ± 2.4, while their body fat percentage was 12.5 ± 1.9%. The firefighters' BMI was 23 ± 4 and body fat percentage 15.2 ± 2.1%. The mine rescue workers' BMI was 27.2 ± 3.1 and body fat percentage 15.5 ± 3.6%. The relation between the rescue groups' BMI and age was statistically significant ($p < .001$). The relation between the number of hours spent on endurance training and $V_{O2\,max}$ among the three rescue groups was also statistically significant ($p < .001$). Tables 3–4 show the results of the most significant items in the Assessment Questionnaire of Physical Fitness.

The regression analysis of the dependent $V_{O2\,max}$ and the independent SAT and the AE showed a clear adjustment (–2LL = 38.921). Nevertheless, only the AE variable was significant ($p < .001$).

TABLE 2. $V_{O2\,max}$ by Age Group

	$V_{O2\,max}$ (ml/min/kg)			
Rescue Group	**Total**	**19–29 years (*n*)**	**30–39 years (*n*)**	**40–49 years (*n*)**
Lifeguards	50.0 ± 11.3	54.0 ± 12.0 (19)	46.0 ± 5.1* (2)	0
Firefighters	43.8 ± 9.4	49.0 ± 9.3 (17)	43.0 ± 11.2* (12)	39.0 ± 8.7** (8)
Mine rescue workers	36.0 ± 9.1	40.0 ± 7.3 (13)	36.0 ± 9.4* (25)	34.0 ± 9.0** (21)

Notes. * = significantly different from the 19–29 group ($p < .001$); ** = significantly different from the 30–39 group ($p < .001$).

TABLE 3. Training Elements According to the Assessment Questionnaire of Physical Fitness

	Lifeguards		Firefighters		Mine Rescue Workers	
	Yes	No	Yes	No	Yes	No
Training Element	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**
Training matches demands of profession	15 (68.1)	7 (31.9)	33 (89.1)	4 (10.9)	27 (45.7)	32 (54.3)
Access to trainer	0	22 (100)	0	37 (100)	0	59 (100)
Self-managed training	13 (59.0)	9 (41.0)	30 (81.1)	7 (18.9)	26 (44.0)	33 (56.0)
Structured training	4 (18.1)	18 (81.9)	15 (40.5)	22 (59.5)	9 (15.2)	50 (84.8)

TABLE 4. Type of Training According to the Assessment Questionnaire of Physical Fitness

	0–1 h			2–3 h		
	LG	FF	MR	LG	FF	MR
Type of Training	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Endurance (per week)	5 (22.7)	3 (8.1)	29 (49.1)	5 (22.7)	8 (21.6)	20 (33.8)
Strength	13 (59.0)	3 (8.1)	20 (33.8)	6 (27.2)	9 (24.3)	15 (25.4)
Speed	15 (68.1)	35 (89.7)	59 (100)	7 (31.8)	2 (5.4)	0
Flexibility	20 (90.9)	30 (81.1)	57 (96.6)	2 (9.0)	7 (18.9)	2 (3.3)

	4–5 h			6–7 h		
	LG	FF	MR	LG	FF	MR
Type of Training	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Endurance (per week)	10 (45.4)	14 (27.8)	4 (6.7)	3 (13.6)	12 (32.4)	6 (10.1)
Strength	2 (9.0)	15 (40.5)	10 (16.9)	1 (4.5)	10 (27.0)	14 (23.7)
Speed	0	0	0	0	0	0
Flexibility	0	0	0	0	0	0

Notes. LG = lifeguards, FF = firefighters, MR = mine rescue workers.

4. DISCUSSION

The main aim of this study was to determine $V_{O2\,max}$ levels, BMI and body fat percentage of three rescue groups and to relate them to the participants' age to examine whether these factors were relevant for rescue groups. The study also aimed to examine the type of training and the subjective perception of physical fitness to assess whether the results corresponded with actual $V_{O2\,max}$.

The results of this study present satisfactory $V_{O2\,max}$ levels among the lifeguards (50.0 ± 11.3 ml/min/kg) and the firefighters (43.8 ± 9.4 ml/min/kg), which are acceptable values for these rescue groups to perform effectively rescue activities [1, 2, 14, 20, 26]. However, the mine rescue workers present very low $V_{O2\,max}$ levels (36.0 ± 9.1 ml/min/kg). These results are slightly lower than those obtained in a previous study, in which mine rescuers had lower results than other rescue groups [27]. According to Stewart, McDonald, Hunt, et al., lower $V_{O2\,max}$ levels among the mine rescue workers depended on several different factors such as irregular training, voluntary nature of rescue groups and average age [15]. Furthermore, a low number of the firefighters' and the lifeguards' rescue actions could be a determining factor for their $V_{O2\,max}$ levels.

The correlation between age and $V_{O2\,max}$ indicates significant levels of inverse correlation (Table 2). However, Kales, Aldrich. Polyhronopoulos, et al. did not record these significant levels for mine rescue workers [17]. Kenny, Yardely, Martineau, et al. argued that properly trained firefighters aged 40–60 could maintain recommended $V_{O2\,max}$ levels [28]. The reason for this correlation could be a decline in training with age rather than age itself, which implies both physical and psychological risks to participants [29, 30, 31]. According to Lusa, Louhevaara and Kinnunen, physical work and the demand for work capacity remained the same throughout a firefighter's career regardless of age and this should not affect a firefighter's performance [12].

The results of the Assessment Questionnaire of Physical Fitness show that no participants had had training with an expert. On the other hand, a high percentage of the participants self-managed their training, although they did not follow any kind of structured plan (Table 3). Most mine rescue teams consist of volunteers and, therefore, their training varies considerably [15]. According to Reilly, Iggleden and Gennser, et al., firefighters' training is voluntary and prepared according to individuals' criteria; they were only required to pass certain fitness tests specific for their work [32]. If a certain type of physical fitness is necessary for joining a rescue group, this fitness should be maintained throughout one's career. However, a study monitoring the first 18 months of new firefighters' training showed that $V_{O2\,max}$ and other physical qualities decreased due to inadequate self-managed training [33].

The firefighters spent most time on endurance training (60% > 4–5 h), next were the lifeguards (59% > 4–5 h) and the mine rescue workers (16.8% > 4–5 h) (Table 4). In spite of a significant relationship between endurance training and obtained $V_{O2\,max}$ ($p < .001$), over 50% of the participants who said they trained 4–5 h did not reach the recommended $V_{O2\,max}$ rate of 43 ml/min/kg [1, 20]. The reason could be an inadequate nature of endurance training carried out according to individuals' criteria.

The applied regression model shows how the AE is a determining variable in predicting $V_{O2\,max}$. Furthermore, the SAT variable does not provide suitable results to determine $V_{O2\,max}$. It is probably because of contributing factors related to social desirability, motivation or cognitive-mediational factors that the AE variable does not present. The SAT depends on decisional factors, which were not analysed in this research.

Nevertheless, the study shows that during training not monitored by an expert, the members of rescue group could subjectively perceive higher than actual $V_{O2\,max}$. Perception error caused by over-rating $V_{O2\,max}$ means that the members of rescue groups would not be able to cope with the physical demands of their occupation [19, 20]. Over-rating actual $V_{O2\,max}$ of the rescue groups could lead to premature fatigue during rescue activities, thus endangering the participants' and the victims' life.

A study of 115 urban firefighters showed that a physical exercise programme monitored by an expert over 16 weeks significantly increased $V_{O2\,max}$; which rose by 28% [11]. Other studies on forest firefighters obtained 6% and 8% improvement in $V_{O2\,max}$ after a 16-week training programme [9, 10]. The main difference between these studies was that the urban firefighters had a very low initial $V_{O2\,max}$ level and poor fitness levels that were easily improved through a supervised training programme, while the forest firefighters began the study with a very high $V_{O2\,max}$. The differences in the groups' initial $V_{O2\,max}$ had a significant connection with the participants' age. A planned training programme, regardless of age, implies responsibility, intensity and exigencies; all factors that can trigger stress if not considered [34].

Firefighters are a group that spends most time on endurance training, on the other hand, lifeguards are a group with the highest levels of $V_{O2\,max}$. This confirms that improper training can lead to unwanted consequences: firefighters spend a lot of time on endurance training, but have lower $V_{O2\,max}$ than lifeguards; therefore, their training is ineffective. Moreover, lifeguards have higher $V_{O2\,max}$ with fewer training hours. Most lifeguards in the present study were competition swimmers (81.8%); this could have increased their knowledge and self-perception of their training, which made them more effective.

Burke and Dunbar-Jackobs warned that rescue groups' training (firefighters) should not solely focus on aerobic or endurance training and that strength should also be an important element [30]; different studies describe strength as important element of rescue groups' functioning [16, 35, 36, 37]. In this study, strength training received the second highest amount of attention among the three rescue groups (Table 4); ~68% of the firefighters, 40% of the mine rescue workers and 13.5% of the lifeguards declared over 4 h a week of strength training. This situation is comprehensible if we consider the firefighters' and the mine rescue workers' tasks involving carrying heavy weights, which requires considerable strength. The victim's weight and the rescuer's strength are decisive factors during a rescue activity and they could complicate rescue tasks for both firefighters and medical rescuers [33, 38]. Mine rescue workers' constant microtraumas, which cause muscle weakness, prove the need for strength training among this group [39]. On the other hand, during water-based rescue tasks, the weight of the rescuer is considerably reduced because of floating, thus the need for strength among lifeguards is reduced [14]. Data from previous studies confirm the results of this study. Speed and flexibility are qualities that are almost completely ignored by rescue groups, in spite of being essential elements in most physical training programmes for elite sportspersons [40, 41].

Firefighters spend most hours on physical training, even if it is self-managed, whereas mine rescue personnel spend the fewest hours. The status of each group may be a determining factor, as firefighters are civil servants (permanent posts), lifeguards only work in the summer and mine rescue workers are volunteers.

There was a negative and statistically significant correlation between the participants' BMI and $V_{O2\,max}$ ($p > .001$). Clark, Rene, Theurer, et al. found that 80.7% of the firefighters from their study were obese or morbidly obese; this caused a negative relationship between their weight and $V_{O2\,max}$ [21]. BMI could be a useful variable when identifying health levels of candidates for rescue groups and deciding on measures improving their performance.

According to Nagaya, Yoshida, Takahashi, et al., monitoring BMI of rescue groups (police, firefighters) was more important than of other professions, because rescue groups maintained optimum health levels guaranteeing satisfactory performance of work-related tasks [42]. Lalić, Bukmir and Ferhatović confirmed that higher BMI was a performance-limiting factor for rescue groups [43].

Using BMI to monitor training among different rescue groups was also suggested in a study of 332 firefighters, whose BMI increased from 29 to 30 in the first year and among whom the level of obesity increased from 35% to 40% ($p < .001$) [22]. Furthermore, Ellam, Fieldman, Garlick, et al. concluded that firefighters' training in their first 18 months of work increased their BMI, showing that their training programme was insufficient. They recommended training prepared by an expert [33].

According to the World Health Organization BMI classification [44], the lifeguards and the firefighters in the present study were within the normal range and the mine rescue groups were overweight. Lalić et al. recorded BMI of 27 voluntary firefighters and 26 professional firefighters; there was a significant relationship between BMI and firefighters' age ($p < .001$) [43]. This data confirm the results obtained in the present study.

Various authors believe that a proper assessment of a sportsperson should involve calculating their body fat and percentage of muscles [45, 46]. However, weight measurements are not reliable data as gaining weight could mean an increase in muscle mass, not fat. Therefore, an incorrect interpretation of this value could misinform sportspersons [45, 47, 48].

According to some studies, the higher the body fat percentage, the worse the person's performance. However, land-based tests showed that the degree of adiposity, rather than the total body weight, influences the performance [24]. The results of this study show that body fat percentage was within the standard parameters for the three rescue groups; the lifeguards' body fat percentage was 12.5%, the firefighters' 15.2% and the mine rescue workers' 15.5%. Because BMI and body fat percentage are not the same in all groups, these indices should be analysed for every participant [49]. However, in the present study, there was a high level of correlation between BMI and body fat percentage and age ($p < .001$), possibly due to a reduction in lean body mass (muscle) over time [50, 51].

It can be concluded that lifeguards' and firefighters' $V_{O2\,max}$ is above the recommended levels, while the mine rescue workers' results are below these levels; therefore, implying a risk to their rescue tasks. The negative correlation between $V_{O2\,max}$ and age in the three rescue groups could be influenced by the type of training (random and individual) and the amount of time (older workers spend less time on training). This confirms the need for rescue groups to follow a structured physical training monitored by an expert to effectively respond to the energy-related demands of their professions. For all these reasons, regular monitoring of the participants' physical condition is essential to avoid age becoming a detrimental factor for the physical health and posing a risk to the effectiveness of rescue work. Future research could establish a maximum age for maintaining the physical conditions needed to be a rescuer. On the other hand, the negative correlation between BMI and $V_{O2\,max}$

confirms the importance of using body fat percentage and BMI to assess the physical health of rescue groups.

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