

## Maximal Oxygen Consumption, Respiratory Volume and Some Related Factors in Fire-fighting Personnel

### Abstract

**Background:** Firefighters for difficult activities and rescue of damaged people must be in appropriate physical ability. Maximal oxygen capacity is an indicator for diagnosis of physical ability of workers. This study aimed to assess the cardiorespiratory system and its related factors in firefighters. **Methods:** This study was conducted on 110 firefighters from various stations. A self-administered questionnaire (respiratory disorders questionnaire, Tuxworth-Shahnavaz step test, and pulmonary function test) was used to collection of required data. Average of humidity and temperature was 52% and 17°C, respectively. Background average noise levels were between 55 and 65 dB. Data were analyzed using SPSS software (version 19). **Results:** The mean age of the study participants was  $32 \pm 6.2$  years. The means of forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), and FEV1/FVC were  $92\% \pm 9.4\%$ ,  $87\% \pm 9.2\%$ , and  $80\% \pm 6.1\%$ , respectively. The participants' mean  $VO_2$ -max was  $2.79 \pm 0.29$  L/min or  $37.34 \pm 4.27$  ml/kg body weight per minute. The results revealed that weight has a direct association with vital capacity (VC), FVC, and peak expiratory flow. In addition, height was directly associated with VC, FVC, and  $VO_2$ -max ( $P < 0.05$ ). However, there was an inverse and significant association between height and FEV1/FVC ( $r = -0.23$ ,  $P < 0.05$ ). Height, weight, body mass index, and waist circumference were directly associated with  $VO_2$ -max. **Conclusions:** The findings of this study showed that the amount of maximum oxygen consumption is close with the proposed range of this parameter among firefighters in other studies. Furthermore, the results of the study revealed that individuals had normal amounts of lung volume index. This issue can be attributed to the appropriate usage of respiratory masks.

**Keywords:** Firefighter, maximal oxygen consumption, respiratory volume

### Introduction

Firefighters and aid workers are considered to be victims of heat stress in physiological activities.<sup>[1]</sup> Moving and lifting heavy objects or saving people under stressful conditions are such activates done by firefighters while wearing protective clothes and a compressed air breathing apparatus.<sup>[2]</sup> Accordingly, they need to have appropriate physical structure to perform their duties properly.<sup>[3,4]</sup> Numerous studies indicated that individuals' appropriate physical performance depends on  $VO_2$ -max, which is defined as the maximum amount of oxygen that can be absorbed by the respiratory system and be sent to operating muscles.<sup>[5-7]</sup> Previous studies showed that  $VO_2$ -max ranged from 33.5 to 45 ml/kg body weight per minute among firefighters.<sup>[8,9]</sup> Based on Kiss *et al.*'s study conducted in Belgium, the rate of  $VO_2$ -max was estimated to be

46.5 ml/kg body weight per minute among firefighters.<sup>[10]</sup>

Moreover, pulmonary function test or spirometry is identified as another method to assess cardiorespiratory system's health. Spirometry is the most common pulmonary function test, giving the rate, volume, speed, or flow of an individual's inhalation and exhalation. The test consists of three main parameters, namely, forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC), and FEV1/FVC. FVC refers to the amount of air an individual exhales from one's lung after a deep inhalation. FEV1 is also defined as the amount of air an individual forcefully exhales from one's lung in the first second of exhalation. Finally, FEV1/FVC is the ratio of the second to the first parameter and indicates the percentage of FVC exhaled from lung in the first second of exhalation.<sup>[11]</sup>

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### Quick Response Code:



In comparison with the society, firefighters have better pulmonary function, particularly in FVC and FEV1 parameters.<sup>[12,13]</sup> However, due to the increase in utilization of chemical materials in buildings in the recent decades, concerns have risen about this group's health.<sup>[14]</sup> Regarding the results of some studies, exposure to smoke and fumes<sup>[15,16]</sup> including acrolein, carbon monoxide, hydrogen chloride, hydrogen cyanide, nitrogen oxides, sulfur dioxide, particles, aldehydes, and carcinogens led to chronic pulmonary damages followed by reduction of pulmonary function.<sup>[13,15-19]</sup> Numerous studies revealed the acute effects of exposure to smoke on firefighters' health, particularly pulmonary function. For instance, according to a study conducted on 28 firefighters, a considerable obstructive pulmonary disease within few hours after exposure to smoke was found.<sup>[20]</sup> In addition, the findings of Musk *et al.* revealed that occurs a significant reduction in FEV1 among smoker peoples.<sup>[15]</sup>

Considering what was mentioned above and firefighters' heavy physical requirements, it is essential to assess their cardiorespiratory function accurately. Hence, this study aimed to investigate respiratory complications and assess of VO<sub>2</sub>-max, lung volumes, and their associated factors among firefighters in one of the central cities of Fars province, Iran.

## Methods

This is a cross-sectional study on firefighters who were participating in fire suppression and rescue operations in one of the central cities of Fars province, Iran. Using a systematic random sampling approach and based on *a priori* sample size calculation, 110 firefighters were selected from various stations among which 104 participants agreed to participate in all the stages of the research. All participants with at least 1 year of working experience were interviewed and those with any history of cardiovascular or respiratory disorders and smoking were excluded from the study.

An self-administered questionnaire was used to collect information on the participant's demographic and respiratory status. This questionnaire used in several studies and its reliability and validity have been approved. It also employed in several studies in Iran.<sup>[12,21-25]</sup>

## Procedure

Pulmonary function tests were measured based on ATS' guidelines using a spirometer (Vitalograph Compact II, England). Given device was calibrated each day and after per 10 tests. Three acceptable spirometry maneuvers, therefore, were obtained from each participant and the best one was recorded. VO<sub>2</sub>-max was evaluated using the protocol developed by Tuxworth-Shahnavaz on an Iranian society in 1977.<sup>[26]</sup> In this protocol, individuals go up and down step (height: 40 cm) with a cadence of 25 times in a minute for 5 min. Then, they sit on a chair, their heart rate is measured in three 30 s stages (M1: 30–60 s, M2: 90–120 s,

and M3: 150–180 s [Figure 1]), and VO<sub>2</sub>-max is computed using the following equations.

$$\text{Index } b = \frac{(M_1 + M_2 + M_3)}{\text{BW (kg)}} \times 2$$

$$\text{Index } b \rightarrow Y = -0.378X + 4.67$$

At the end of the interview, anthropometric indexes (weight and height) were measured. Participants with minimal clothing and no wearing shoes were weighed with a calibrated digital platform Balance Scale (Imperial BS 412, US) and the numbers were rounded to the nearest 100 g. Height was measured while the participants were in standing position with the shoulders in a normal resting and also 3 regions of their body (buttocks, heel, and head) touching the wall, without wearing shoes. In addition, temperature and relative humidity were measured using thermometer, spinning thermometer (Casella, England), and psychrometric chart. Environmental measurements indicated that the mean humidity was 52 and the mean temperature was 17°C. Moreover, the noise of environment was measured using sound level meter (model TES-1351) manufactured by Taiwan.

## Statistical analysis

The sample size was calculated to detect at least 2.3 kg change in weight with alpha value of 0.05 and a power of 80%. Data were analyzed using Statistical Package for Social Sciences 19 (SPSS Inc, Chicago, IL, USA). The main study variables included both quantitative (age, height, weight, waist circumference, body mass index [BMI], and job tenure in firefighting) and qualitative measures (marital status, level of education, second job, and job satisfaction). Pearson's correlation coefficient was used to assess the association between demographic and anthropometric variables with respiratory volume and maximal oxygen consumption.

## Results

The demographic and environmental characteristics of participants are shown in Table 1. Environmental measurements indicated that the mean humidity was 52 and the mean temperature was 17°C. Based on Table 2, more

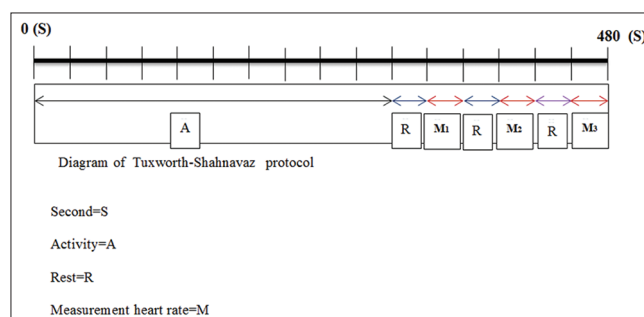


Figure 1: Diagram of Tuxworth-Shahnavaz Protocol

**Table 1: Some demographic characteristics of the studied fire-fighting personnel (n=110)**

Quantitative variable	Mean±SD	Minimum-maximum
Age (years)	32±6.2	22-48
Weight (kg)	76±9.9	52-102
Height (cm)	176±5.8	160-190
BMI (kg/m <sup>2</sup> )	24±2.7	17.99-32.27
Waist (cm)	84±5.1	72-106
Overall work history (year)	9±6.3	1-25
Worked in fire (year)	6±6.2	1-25
Qualitative variable	n (%)	
Marital status		
Married	76 (69.1)	
Single	34 (30.9)	
Level of education		
Without academic education	67 (60.9)	
With academic education	43 (39.1)	
Second job		
Yes	10 (9.1)	
No	100 (90.9)	
Job satisfaction		
Rather dissatisfied	11 (10)	
Indifferent	2 (1.8)	
Quite satisfied	97 (88.2)	
Change jobs		
Yes	27 (24.5)	
No	82 (74.5)	

BMI=Body mass index, SD=Standard deviation

**Table 2: Distribution of respiratory complications among studied fire-fighting personnel (n=110)**

Respiratory symptoms	Yes, n (%)	No, n (%)
Shortness of breath	20 (18.2)	90 (81.8)
Chest compression	7 (6.4)	103 (93.6)
Coughs	11 (10)	99 (90)
Phlegm	119 (17/3)	91 (82.7)
Coughs and phlegm	9 (8.2)	101 (91.8)
Wheezing	10 (9.1)	100 (90.9)

**Table 3: Mean, standard deviation, minimum and maximum lung volumes, and maximal oxygen consumption of studied fire-fighting personnel (n=110)**

Variable	Mean±SD	Minimum	Maximum
VC	91±8.9	63	114
FVC	92±9.4	68	120
FEV <sub>1</sub>	87±9.2	61	110
FEV <sub>1</sub> /FVC	80±6.1	63	95
PEF	98±15.6	46	139
FEF 25%-75%	73±19.4	23	125
VO <sub>2</sub> -max (L/min)	2.79±0.29	1.96	3.70
VO <sub>2</sub> -max (mL/kg/min)	37.34±4.26	28.66	50.00

SD=Standard deviation, VC=Vital capacity, FVC=Forced vital capacity, FEV<sub>1</sub>=Forced expiratory volume in 1 s, PEF=Peak expiratory flow, FEF=Forced expiratory flow, VO<sub>2</sub>-max=Maximum oxygen consumption

than 80% of the participants had no respiratory disorders. The lung volumes and VO<sub>2</sub>-max of the study participants are shown in Table 3. Accordingly, the means of FVC, FEV<sub>1</sub>, and FEV<sub>1</sub>/FVC were 92% ±9.4%, 87% ±9.2%, and 80% ±6.1%, respectively. The mean of VO<sub>2</sub>-max was 2.79% ±0.29 L/min or 37.34 ± 4.27 ml/kg body weight per minute.

The results of Table 4 show a significant association between age and peak expiratory flow (PEF) ( $r = 0.19$ ,  $P = 0.045$ ). In addition, height was directly associated with vital capacity (VC) ( $r = 0.23$ ,  $P = 0.016$ ), FVC ( $r = 0.26$ ,  $P = 0.007$ ), and VO<sub>2</sub>-max ( $r = 0.39$ ,  $P = 0.001$ ). However, there was an inverse and significant association between height and FEV<sub>1</sub>/FVC ( $r = -0.23$ ,  $P = 0.017$ ). Moreover, a significant and direct association between weight and FVC ( $r = 0.20$ ,  $P = 0.034$ ), PEF ( $r = 0.24$ ,  $P = 0.012$ ), and VO<sub>2</sub>-max ( $r = 0.53$ ,  $P = 0.001$ ). In addition, the finding revealed a significant direct association between BMI and VO<sub>2</sub>-max ( $r = 0.39$ ,  $P = 0.001$ ). Finally, waist circumference showed a significant direct association with VO<sub>2</sub>-max ( $r = 0.33$ ,  $P = 0.001$ ).

## Discussion

This is a cross-sectional study that examined the relationship between some factors linked to individuals' capabilities with the cardiorespiratory factors. Moreover, considering the importance of pulmonary function tests in diagnosis and treatment of respiratory disorders, determination of normal lung volumes is essential in different societies.<sup>[27]</sup> In addition to lung volumes, determination of VO<sub>2</sub>-max seems to play an important role in occupational ergonomics. However, few studies have been conducted in this area among firefighters. As a result, the effective factors in VO<sub>2</sub>-max have remained unknown.

The aim of this study was to investigate cardiorespiratory health among firefighters in one of the central cities of Fars province, Iran. Accordingly, the mean of FVC, FEV<sub>1</sub>, and FEV<sub>1</sub>/FVC was normal which is in accordance with the report published by Michael *et al.*<sup>[28]</sup> Based on the Sharifian's findings, FVC was lower in Iran compared to European and American countries.<sup>[29]</sup> Based on the results from a study conducted by Alizadeh, height is one of the effective factors in lung volumes.<sup>[30]</sup> Accordingly, the lower lung volumes in the present study which is not in accordance with the Michael's finding<sup>[28]</sup> might be attributed to height differences between both societies.

In the current study, the firefighters' main complaints included shortness of breath followed by phlegm and cough, which is consistent with the findings of the study by Rothman *et al.*<sup>[31]</sup> In addition, Rahimi Moghaddam (2014) suggested that the most frequent complaints were phlegm, wheezing, and cough among welders.<sup>[32]</sup> Aminian also showed that cough is the most common complaint among the individuals working in textile industries.<sup>[33]</sup>

**Table 4: Association between demographic variables with respiratory volume and maximal oxygen consumption**

Variables	FEF 25%-75%	PEF	FEV <sub>1</sub> /FVC	FEV <sub>1</sub>	FVC	VC	VO <sub>2</sub> -max (L/min)
Age (years)							
<i>r</i>	-0.043	0.196	-0.09	-0.1	-0.12	-0.09	-0.04
<i>P</i> *	0.662	0.045	0.373	0.322	0.227	0.336	0.769
Weight (kg)							
<i>r</i>	0.079	0.246	-0.142	0.142	0.208	0.184	0.533
<i>P</i> *	0.426	0.012	0.148	0.148	0.034	0.06	0.001
Height (cm)							
<i>r</i>	0.027	0.077	-0.233	0.135	0.260	0.236	0.398
<i>P</i> *	0.781	0.436	0.017	0.170	0.007	0.016	0.001
Waist circumference (cm)							
<i>r</i>	0.053	0.165	-0.115	0.067	0.112	0.100	0.33
<i>P</i> *	0.591	0.093	0.242	0.496	0.257	0.311	0.001
Job tenure in fire-fighting (year)							
<i>r</i>	-0.039	0.077	-0.043	-0.132	-0.176	-0.076	-0.02
<i>P</i> *	0.963	0.439	0.662	0.183	0.074	0.446	0.433
BMI (kg/m <sup>2</sup> )							
<i>r</i>	0.083	0.247	-0.027	0.100	0.102	0.089	0.399
<i>P</i> *	0.394	0.110	0.786	0.309	0.302	0.365	0.001

VC=Vital capacity, FVC=Forced vital capacity, FEV<sub>1</sub>=Forced expiratory volume in 1 s, PEF=Peak expiratory flow, FEF=Forced expiratory flow, VO<sub>2</sub>-max=Maximum oxygen consumption, BMI=Body mass index. \*Significance level: 0.05

The results of the present study showed a significant and direct association between age and PEF, whereas other studies could not find such direct associations.<sup>[34,35]</sup> In contrast, Aldrich *et al.* (2010) reported a 25 ml decrease in FEV<sub>1</sub> each year after exposure.<sup>[36]</sup> Accordingly, significant reduction of these parameters with age is most probably due to their unprotected exposure to smoke.

In the present study, height was significantly and inversely associated with VC and FVC. Weight, on the other hand, showed direct association with VC, FVC, and PEF which are in accordance with the result of a study conducted by Alizade *et al.*<sup>[30]</sup> Mehrabi and Kargarfard on the other hand found an inverse association between weight and lung volumes.<sup>[37]</sup> It could be attributed to overweight resulting from fat tissues and lack of physical activity among the participants. According to the results of the present study, participants had high BMI due to increase in their muscle mass resulting from regular physical activities. Regarding the findings from the Spathopoulos *et al.*,<sup>[38]</sup> Gundogdu and Eryilmaz,<sup>[39]</sup> and Furutate *et al.* (2011),<sup>[40]</sup> excess fat tissues hinder appropriate pulmonary function that can, in turn, affect cardiovascular function. Sothmann *et al.* suggested that VO<sub>2</sub>-max ranges should be from 33.5 to 42 ml/kg body weight per minute among firefighters.<sup>[41]</sup> However, the previous studies raised some controversial issues over the VO<sub>2</sub>-max values and suggested that certain circumstance including physical, mental, environmental, and physiological factors<sup>[42,43]</sup> of different individuals might be significantly different.<sup>[44]</sup> Role of the protocol utilized in the current study should be taken into account as well. In this study, the researchers made use of Tuxworth-Shahnavaz protocol that has been proposed for Iranian communities.

Furthermore, the difference between the results of our study and the one performed by Kianmehr and Nazem<sup>[45]</sup> might be attributed to the participants' mean age because VO<sub>2</sub>-max decreases with increase in age<sup>[46-48]</sup> and the highest amount of VO<sub>2</sub>-max has been observed in the age range of 18–25 years.<sup>[42]</sup>

Results of the present study indicate a significant and direct association between height, weight, BMI, and waist circumference with VO<sub>2</sub>-max. These results are not fully in accordance with a report published by Daneshmandi *et al.* detected a direct but not significant association between height and VO<sub>2</sub>-max.<sup>[49]</sup> The authors suggested that reduction in VO<sub>2</sub>-max decrease height due to change in muscles' structure<sup>[50-54]</sup> and faded the relationship between height and VO<sub>2</sub>-max.

Although the present study findings demonstrated a descending trend in VO<sub>2</sub>-max with increase in age, the association was not significant. Previous studies indicated a considerable decrease in VO<sub>2</sub>-max with increase in age.<sup>[46-48]</sup> The nonsignificant association observed in the current study might be attributed to the participants' small age range, which might have faded the effect of age. Furthermore, VO<sub>2</sub>-max was significantly lower in the individuals with normal BMI compared to those with high BMI. However, the results of the study conducted by Daneshmandi *et al.* (2013) revealed an inverse linear relationship between VO<sub>2</sub>-max and BMI (*r* = -0.158). What's more, VO<sub>2</sub>-max was higher in the individuals with normal BMI in comparison to overweight and obese ones.<sup>[49]</sup>



## Conclusions

The ability of people to do their job is influenced by the person's capabilities, the job demand, and the condition under which the person is carrying out the job. The findings of this study showed that the amount of maximum oxygen consumption is close with the proposed range of this parameter among firefighters in other studies. Furthermore, the results of the study revealed that participants had normal amounts of lung volume index. This issue can be attributed to the appropriate usage of respiratory masks.

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## Conflicts of interest

There are no conflicts of interest.

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