Evaluation of validity and capability of professional function test of Iranian firemen

Kianmehr P.¹ MSc, Nazem F. * PhD

*Department of Physical Education & Sport Science, Faculty of Literature & Humanities, BualiSina University, Hamedan, Iran; ¹Department of Physical Education & Sport Science, Faculty of Literature & Humanities, BualiSina University, Hamedan, Iran

Abstract

Aims: Firemen must have appropriate physical fitness in order to do their tasks perfectly and perform their special function under different and critical conditions with the least mortality. The aim of the present study was to evaluate the correctness and capability of Iranian male firefighters’ functional tests proportionate to their cardiovascular fitness.

Methods: This descriptive-analytical study was performed in 2010. 25 newly employed firemen with the age range of 23-36 were selected voluntarily by available sampling, from among 90 employment applicants of four firefighting stations of Tehran, Iran and Hong Kong’s index functional tests were held in standard condition and the temperature of 19-21 centigrade degrees. The firefighters’ aerobic power was evaluated by direct method of respiratory gas analysis. Kolmogorov-Smirnov test and linear regression were used for data analysis.

Results: Firefighters’ VO₂ max had a weak correlation with Index tests of Hong Kong (R=0.23 and SEE=0.03) and Iran (R=0.03 and SEE=0.15) that was not statistically significant (p>0.05).

Conclusion: Although having the threshold aerobic power is the desirable level for evaluation of firefighters’ cardiovascular fitness in this hazardous career, the studied population lacks appropriate physical fitness considering the special function in relief missions and firefighting. Revision and editing of the components of firefighters’ functional tests is recommended.

Keywords: Aerobic Power, Firefighting Functional Tests, Cardiovascular Fitness

Introduction

Firefighters always witness different incidents and injuries in different occupations of society and especially they do their best in fire rescue scenes. These are the firemen who work in very difficult environmental situation to save the life and properties of their counterparts. Therefore, they are always exposed to different injuries [1, 2, 3]. This group of society must have appropriate physical fitness to do their duty in optimal level. In this way, they can do their professional tasks properly and with the least mortality in totally critical and different situations and with the presence of different elements such as psychological stress, using protective clothes, changes in environment (warm or hot or very cold), etc. [4, 5]. Studies show that the fireman encounter with the threats of external stress such as heat (smoke and fire), chemical dangers, falling down and coldness during their tasks and they need higher levels of energy due to their muscular function according to their professional tasks [5, 6, 7]. On the other hand, many operations or social occupations require a high level of body activity [8]. Scientific evidences show that the increase in volume and the intensity of physical activity can decrease the cardiovascular diseases among the firemen [4, 9 and 10]. During their work, firemen have to tolerate the maximum of working pressure [11, 12]. However, aerobic fitness can improve the operation and their relative cardio-respiratory steady state. Doing any task especially physical occupations needs appropriate power and saving the aerobic power. The studies show that the oxygen cost of a firefighter is 60 to 80% of its maximum amount during the saving and rescuing operation [13]. In addition, the inactive official staff has 90% or more the possibility of having cardiovascular diseases compared to the people who have optimal physical fitness [14]. The World Firefighting Organization has reported the cardiovascular disease as the main reason of job related death and physical damages finally early withdrawal from the firing service among firemen. A broad study in this domain shows that the cardiovascular diseases are increasing in the fire fighters [15]. It should be noted that firefighters’ low level of aerobic power is the important problem that expose them to cardiovascular disease along with factors such as sudden change of organism from the rest position to high activity during the rescuing activities, psychological and environmental stresses and using heavy protective clothes [16]. Scientific evidence shows that the heart rate is much more in hot environment compared to the normal temperature.
The heart rate increases in the hot environment or during isometric muscular contraction and psychological anxiety. These are normal events during the tasks of firemen. Besides the reaction of heart rate during the firefighting tasks, there is negative and significant relationship between the operation time and the VO\textsubscript{2,max} of the firefighting volunteers. Generally speaking, these findings show that these individuals can tolerate the average working condition of 73% of VO\textsubscript{2,max} during 9 minutes. In other words, it can be said that the best fireman is the quickest one [17].

One of the physiological signs of an organism is the optimal heart beat and better cardio-respiratory readiness in real emergencies of firefighting and rescue, because with increase in the amount of VO\textsubscript{2,max}, the amount of philological readiness and the response to the cardiovascular system to a specific physical activity improves [18, 19, 20]. The studies show that the amount of required energy for the main operations of fireman including installing and ascending the stairs and moving and pulling the hoses is of the main elements of their professional operation. In a study, the physiological variables of heart rate and oxygen cost of 20 volunteer firemen were considered in the laboratory and similar environment to the real operation of firefighting (without using the protective clothes and oxygen capsule) that the amount of VO\textsubscript{2} max of firefighters came out to be more than 40ml/kg and the their heart rate came out to be 176±10 beats per minute. Some other reports have shown the essential needs of fireman. In this regard, effective factors on the firemen’s performance including the body components, psychological stress and the environmental heat have led to the drop of function. These conditions hinder their movement and advancement. Finally, evaluating the function in steady laboratory environment or fire maneuver is difficult that it is one of the main problems in this type of research [21].

The results of Sothmann’s study indicate the existence of anxiety and its effect on firemen’s respiratory system during missions. The problem seen in his study is that the functional tests and the time of performance in each stage of firefighting have not been expressed [12]. Sothmann et al. considered age as another limiting factor of function. They tried to determine the minimum amount of aerobic readiness in firemen. In this study the operation of 150 firemen and their sport operation were investigated in accordance to their cardiovascular situation. They determined VO\textsubscript{2,max} as a sensitive index in evaluating the cardiovascular function and the sport operations and they reported the relative values of aerobic capacity equal to 33.5ml/kg min as the minimum level for evaluating the cardio-respiratory function for emergency tasks [22]. On the other hand, the metabolic requirements (VO\textsubscript{2}) of a small group of firemen during special exercise with carrying the analyzer apparatus of breathing gases was measured. The cost of metabolism, the time of performance and the raw score of the conducted task were registered that were significantly lower than the findings of Sothmann. The aerobic fitness of fireman was 39±5ml/kg min that was equal to 3.3±0.4lit/min. The average VO\textsubscript{2} cost of firemen was 2.5lit/min during the maneuver that was indicative of 76% of their VO\textsubscript{2,max}. In addition, the average of their heart rate was 173±9 beats per minute, the duration of the maneuver was 9 minutes and the minute ventilation was 7.46±3.4lit/min [23].

The purpose of this study was to evaluate the correctness and capability of professional functional tests in Iranian firemen proportionate to their cardiovascular fitness level.

**Methods**

This study is descriptive-analytical type conducted in 2010. The research population was 90 firemen with the age range of 21 to 36 years among whom 30 volunteers were chosen by purposive sampling through advertising in 4 firefighting stations in Tehran. By using the table of Morgan et al. for estimating the sample volume, 25 firemen participated in this project. These people were passing the stages of employment. None of the subjects had cardiovascular, metabolic and orthopedic diseases after completing the PAR-Q questionnaire (the Physical Activity Readiness Questionnaire). In addition, electrocardiogram at the rest position was taken in the Olympic laboratory. There were individuals among volunteers who had sport experiences such as participating in national competitions that these people were excluded. In addition, 5 samples were injured and 5 withdrew during the study.

All the subjects who participated in the trial stages of the tests had 8 hours sleep and enough rest the night before the test and were exempted from doing any official mission. The subjects were advised not to use any type of exogenous drugs and stimu1i such as caffeine and cocoa derivatives. The function test was done in station no.44 of Tehran. The volunteers completed the personal specifications list according to the regulations of the Firefighting Organization. Then the details of performing the two tests were explained to them using the filming method.

The performing of functional test including the handy
The three stage tube and ascending the stairs were carried out based on time. Each case of error increased the time of performing the assignment of each person according to the defined method of the related organization. This test was held with the supervision of the firemen and with observing all the educational and safety issues.

The next stage was performing the index functional test (Hong Kong) that was standardized with the International Organization of Rescue and Firefighting [24]. This test was conducted by two referees with the interval time of 10 days similar to the Iranian functional test. The first referee had the duty of recording the errors in each station and second referee had the duty of announcing the time of starting and recording the time. This test included four elements of ascending the stairs, ascending the ladder, passing through the tube and passing through the obstacles. The results of each volunteer in functional test were recorded based on the time of performance with regarding the error of each volunteer [1, 24].

In the third stage the subjects were distributed in four stations of Tehran after corresponding with the city central fire center. A week after performing the main test (task), the firemen were randomly divided into 5 groups that in each group they were 5 subjects. They were investigated by the sport physiology specialist in the laboratory of The National Olympic Academy for measuring the cardiovascular variables including respiratory gases (VCO$_2$, VO$_2$), respiratory quality (RQ), and Lactate threshold equal to 92% of the maximum consumed oxygen, the sport heart rate, work intensity (VO$_2$max), pulse oximetry and aerobic power. Measuring of aerobic capacity was done by analyzing the respiratory gases (VO$_2$, VCO$_2$), THR and RQ in the 15 ending seconds of each 3 minute stage of working with treadmill work under the specific load (the roller speed and the apparatus slope) with observing two indexes 1.1<RQ and HR$_{max}$, 0.9<THR by automatic machine (Quark-B$_2$ made in Italy) [25, 26, 27, 28]. The information was recorded in the memory of the computer (COSMED, United States). In Bruce protocol, at first the subjects walked in the temperature of 22.3°C for 5 minutes with the pulse range of 95 to 118 beats per min on the apparatus. Then machine started with the speed of 3km/h and 1km/h was added to the previous speed each minute. People were verbally encouraged at the time that they reached the threshold level of lactate until they reached the maximum tiredness [29, 20].

At first the data of two tests were presented based on the descriptive statistics. Then, Kolmogorov-Smirnov test was done for investigating the situation of data distribution and the normal distribution of data was determined (Z=0.49, p=0.97). Also, in investigating the relation between the two functional tests, linear regression was used. The level of difficulty of the test proportionate to the spent time on each element of the two tests that are dependent to the parameters of speed, carefulness, agility, muscular endurance and the coordination of subjects, were measured with the histogram and Q-Q diagrams. Also, the patterns of relationship between the indexes of cardiovascular indexes i.e. aerobic power (VO$_2$-max) were investigated with both tests by linear regression. The statistical findings were evaluated considering the observation of the error type one (Alfa of 5%).

### Results

The anthropometric indexes and the results of the functional test of participating firemen have been brought in Table 1. The time record of the performance of these people in Iran functional test was 1.52 to 2.13 minutes and it was 0.22 to 0.35 minutes in the Hong Kong index test (Table 1).

<table>
<thead>
<tr>
<th>Variables Statistics</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI (kg/m$^2$)</th>
<th>Functional test of fire fighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>73.76</td>
<td>176.3</td>
<td>23.63</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>SD</td>
<td>9.96</td>
<td>5.52</td>
<td>2.59</td>
<td>Iran</td>
</tr>
<tr>
<td>Minimum</td>
<td>53</td>
<td>164</td>
<td>18.5</td>
<td>0.22</td>
</tr>
<tr>
<td>Maximum</td>
<td>96</td>
<td>188</td>
<td>28.7</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Measuring the aerobic capacity was equal to 40 to 55 ml in the direct method and the frequency of heart rate on the treadmill was 163 to 200 beats per min equal to 44 to 90% of their aerobic power (Table 2).

### Table 2 - Physiological variables during the maximum work with the treadmill in firemen

<table>
<thead>
<tr>
<th>Variables Statistics</th>
<th>Intensity of work %VO$_2$MAX</th>
<th>Heart rate (bpm)</th>
<th>VO$_2$MAX (ml/kg/min)</th>
<th>Pulse Oximetry (ml/bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>72.72</td>
<td>181.56</td>
<td>47.53</td>
<td>19.21</td>
</tr>
<tr>
<td>SD</td>
<td>11.97</td>
<td>9.79</td>
<td>3.74</td>
<td>2.74</td>
</tr>
<tr>
<td>Minimum</td>
<td>44</td>
<td>163</td>
<td>40.07</td>
<td>13.80</td>
</tr>
<tr>
<td>Maximum</td>
<td>90</td>
<td>200</td>
<td>55</td>
<td>25</td>
</tr>
</tbody>
</table>

A medium correlation was observed between the two functional tests (Table 3). However, the amount of the proportion was not significant considering the
The coefficient of determination ($R^2=0.28$).

### Table 3: The relationship between the means of Iran functional test and the index of Hong Kong

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Iran</th>
<th>Hong Kong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>1.79</td>
<td>0.26</td>
</tr>
<tr>
<td>SEE</td>
<td>0.131</td>
<td>0.131</td>
</tr>
<tr>
<td>R</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Level of significance</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

## Discussion

Firefighting has been introduced as a very difficult occupation. The key operations in this occupation include carrying the handy ladder, walking up the stairs, working with hose, searching and saving and working with tools. Although there is no agreement upon the time, intensity, revision, the period of rest and working details of firemen, the density and the high degree of the difficulty of their job is being determined under different environmental and geographical conditions. Therefore, in more than 30 case studies, factors such as the amount of consumed energy, heart rate, body central heat and aerobic power have been reported as the key elements in the duties of firemen.

In addition, gathering data, evaluation and quantification of firefighting situations in real operation scenes is a very difficult task. Lack of serious agreement upon the excessive use of equipment, the weaknesses of national and international organizations in standardization of operations and the lack of controlling the amount of work are among the obstacles that cause disability in presenting accurate explanation of physical requirements of firemen and effective factors in removing their organism problems [16, 30].

Firefighting like nursing, mining, piloting and being a war veteran are among the stress inducing occupations and it among physically and mentally dangerous occupations. The most related statistics that are reported for firefighters are accidental and sudden damages, cardio-respiratory diseases and early death. The probable health threatening danger in firemen causes in time of duty performance, it is better to make the balance between the work conditions and the physical fitness level. In addition, considering the physiology of cardiovascular system and the ability of their body operation during a real active maneuver, the tiredness can be reduced or postponed [31]. On the other hand, the scientific evidences explain that the aerobic power alone cannot play an important role in this profession for the standardization of the least physiological requirements for optimal organizational duty, [16, 30, 32, 33, 34].

Regarding this issue, Raven et al. explained that the level of work intensity is very high considering the duration of time spent in performing the saving operations. Therefore, the amount of VO$_2$max should be measured proportionate to the type of work intensity. In other words, evaluating the ability of organism or the operation of fireman is highly influenced by the minimum performance duration in the saving operation. In addition, because of high intensity of work, high temperature, fire-resistant cloths, carrying heavy equipment and especially psychological and environmental anxiety of the firemen, a standard physiological criterion cannot be determined for the firemen solely based on the laboratory research. Anyway, if people have high level of physical and aerobic power, they can perfectly do the firefighting operation along with keeping safety and health. These researches have suggested the aerobic capacity for obtaining the readiness of firefighters equal to 31±7ml/kg per min with the heart rate equal to 176±9 pulses per min and they have evaluated the intensity of firefighters’ work based on the relationship between the cost of energy and the duration of performing the operation equal to 73±10% of their VO$_2$max with the aerobic range of 54 to 88% of aerobic power [17, 35].

Peat et al. suggest that having appropriate aerobic capacity is the required readiness for entering the firefighting occupation. In this way, ready firefighters have 90% probability of exposure to the heart diseases compared to the firefighters who don’t have physical activity. They have introduced the aerobic power of more than 42ml/kg per min as the optimal level for firefighters. However, they have suggested the aerobic power of more than 33.5ml/kg per min as the accepted threshold level for success in firefighting occupation. However, other reports show that this level of cardiovascular readiness with the BMI less than 25kg/m$^2$ do not help them in performing the organizational duties and they need movement readiness parameters such as agility and balance for increasing the efficiency [8, 36, 37, 38]. Bilzon et al. emphasized that appropriate physical fitness before entering the firefighting organization is a good reason for being sure about the health of person. If the volunteer is completely healthy, he can be successful in performing difficult firefighting tasks. In his study,
power, muscle endurance, flexibility of muscles and the personal power were reported as mediating factors in firefighting operations. They reported the maximum aerobic power equal to 41ml/kg per min as the satisfactory level in the firefighting profession [39]. On the other hand, Nav et al. presented the three elements of muscular power, the anthropometric index of height and aerobic readiness as main elements of faster performance of firefighting tasks. They chose the task of saving the injured (that allocates the maximum energy in different rescue operations). The VO$_2$max was obtained 3.7±0.5lit/min equal to 84% of the firefighters’ VO$_2$max. The important issue was the effective factors in speed of performing the maneuver during the rescue operations. Being tall and having appropriate weight and BMI were introduced as the effective factors on faster saving operations. In this study the VO$_2$max of the firefighters was reported at least 4lit/min [7, 32, 35, 40, 41]. In addition, Clark et al. considered the BMI as an effective factor on the firefighting operation. They mentioned this point that people with the BMI of less than 25 (that is acceptable by the WHO) are appropriate for firefighting. This is while in people with the BMI of more than 25 there is the probability of different diseases such as cardiovascular disease, diabetes and hypertension. Because of the firefighting is a difficult job and high physical fitness is required for rescue operations, considering the BMI besides the physiological and movement readiness parameters is essential [42, 43, 44].

The findings of current research show that the 25 firemen of Tehran with BMI index ranges from 18.5 to 28.7kg/m$^2$ and the average BMI of 23.6Kg/m$^2$ are qualified for firefighting according to the standard definition of WHO. In addition, the elements of the Hong Kong index functional test that are close to the cultural and geographical circumstances and the facilities of Iran, shows a medium correlation with the Iranian functional test (R=0.56, SEE=0.13). What should be considered is that the distribution of the record of maneuver operation time in index test (Hong Kong) has a negative skew. This factor is an index for evaluating the speed and coordination in maneuver and physical movement of fireman during the rescue task and less people could achieve the acceptable standard score compared to the Iranian routine test. Therefore, the volunteers reported the performing of the index test more difficult that the Iranian functional test. The amount of correlation between the two functional tests is equal to R$^2$=0.28; it means that almost 70% of the correlation between the two functional tests are affected by other mediating factors that perform their role outside the existing elements. In other words, even 50% of the performing time or recording the firefighting operations in the Iranian test cannot be predicted based on the score of the index test.

Therefore, although Iranian firemen have proper body components and optimum respiratory level, they require more movement abilities for participating in dangerous maneuvers. Therefore, the Hong Kong test index can be recommended for better evaluation of Iranian firefighters’ movement fitness. However, comparing these two tests in real maneuver condition, putting on the protective cloths and the biophysiological variables during the performance need further study.

Conclusion

Although having a proper level of aerobic power is the optimal issue for evaluating firefighters’ cardiovascular readiness in this dangerous profession, the studied individuals do not have appropriate moving readiness while rescuing, saving or firefighting. The review and revision of the elements of functional test lists of Tehran firemen is recommended.

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