Validation of a 6-Minute Step Test for Predicting Maximal Oxygen Consumption in Healthy Individuals Aged 20-40 Years

Hadi Eshaghi Sani Kakhaki¹, Seyed Mostafa Sajjadi²*, Elham Boushehri²

¹Department of Occupational Medicine, Shahid Mohammadi Hospital, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
²Assistant professor of medical education, public health group, health school, Hormozgan university of medical science

*Corresponding Author: Seyed Mostafa Sajjadi

INTRODUCTION

Job needs are diverse in different jobs, so a person who is considered to do a job must be able to do that job for a certain period of time. If the work needs exceed the capacity of a worker for sustainable physical work, he will inevitably get tired. Aerobic testing in the workplace may
serve two purposes: assessing workers' health to promote health and assessing workers' work capacity. Physical fitness is necessary for risky jobs, especially when it comes to public safety. Physical fitness is related to aerobic capacity, anaerobic capacity, muscle strength, endurance, flexibility and coordination. A physiological limit of 30% to 40% is acceptable for a work of eight hours a day, which should be achieved by performing clinically feasible methods. There are several methods for measuring maximum aerobic capacity [1].

In this study, we discuss how cardiovascular aerobic capacity is related to individual ability to do work, as well as how aerobic capacity can be assessed. The maximum aerobic capacity is the maximum oxygen consumption and is expressed in liters of oxygen per minute or milliliters of oxygen per kilogram of body weight per minute. Maximum oxygen consumption ($\dot{V}O_{2max}$) is the maximum amount of oxygen consumed during maximal physical activity. If the intensity of activity reaches a point beyond the maximum oxygen consumption, the oxygen consumption either reaches the cup state or decreases slightly. In such a case, the heart rate is estimated in the range of (± 10) beats per minute [2].

The six-minute walk test is a simple practical test that requires a hundred feet and does not require sports equipment or advanced training. This test evaluates the systems involved during exercise, including the cardiopulmonary system, the circulatory system, the peripheral circulation, and the neuromuscular units and muscle metabolism. Many studies have been done on these exercises in different populations of men and women [3-6]. In a study conducted by Lee in 2018 on the validation of the six-minute walk test and the cardiopulmonary fitness test in type 2 diabetic patients, the average distance traveled during the six-minute walk test was $54 \pm 5.38$ meters and the average heart rate was $93 \pm 11$ beats per minute after the step test. A significant correlation was found between the distances covered during the cardiorespiratory fitness test ($\dot{V}O_{2max}$) and those covered the 6-minute walk test ($r = .542, p < .01$) and step test ($r = -.490, p < 0.01$) in the patients with type 2 diabetes mellitus. Regression equations for the prediction of $\dot{V}O_{2max}$ were constructed from the distance covered, heart rate, age, weight, height, fasting blood glucose level, 2-hour postprandial glucose level, and glycated hemoglobin level during the 6-minute walk test and step test[7]. Results of the study by Hong et al. (2019) regarding step test validation and 6-minute walking in healthy young people showed that both 20 and 30 cm step tests were valid for estimating maximum aerobic capacity and only a strong correlation was
observed between 30 second heart rate and maximum aerobic capacity. Also, their study on estimating maximum aerobic capacity was confirmed by a six-minute walk test and the estimate of maximum aerobic capacity in a 6-minute walking test was valid and ranged from 0.771 to 0.910 [8]. Burr et al. [9] examined the 6-minute walk test as an objective predictor of aerobic fitness of working-age adults on 44 people, including 23 men and 21 women. A strong correlation was observed between the six-minute walking test interval and the maximum oxygen consumption (r = .49 and p = .001). Using multiple stepwise linear regression, the six-minute walk test was performed using a combination of participant body weight, sex, resting heart rate, and age based on the following equation:

\[
Vo2\text{max} = 70.161 + (0.023 \times \text{distance}) - (0.276 \times W) - (6.79 \times \text{Sex}) - (0.193 \times \text{rest HR}) - (0.191 \times \text{Age})
\]

Based on the findings of previous studies and the need for a valid alternative test to measure the aerobic capacity of individuals, the purpose of this study is to compare and validate two practical methods of functional endurance. Specifically, the 6-minute walk test and the 3-minute step test are compared and validated to determine their suitability for use as a field test.

**MATERIAL AND METHODS**

The present study was a cross-sectional descriptive-analytical study. The study population was healthy individuals between 20 and 40 years old who referred to the occupational medicine clinic of Shahid Mohammadi Hospital in Bandar Abbas, Iran in 2020. Sample size based on the study of Tierney et al. [10] and using \( n = \left( z^2 \times s^2 \right) / d^2 \) at 95% confidence level, 90 people were identified and selected by available sampling method.

Inclusion criteria include ability to perform step test and 6-minute walk and exclusion criteria include having 1- history of cardiovascular disease 2- history of smoking 3- history of lung diseases 4- history of drug use 5- history of diabetes 6- History of Covid-19 and a history of hospitalization.

In this study, the step test was used as a standard and the 6-minute walk test was validated based on it. All individuals who referred to the Occupational Medicine Clinic of Shahid Mohammadi Hospital in Bandar Abbas at the time of the project and had inclusion criteria and no exclusion criteria and could perform step test and six-minute walk on two different days, were surveyed.
After recording the age, sex, height and smoking status and history of heart and lung diseases or similar problems were tested and first the heart rate was measured before the test and then the heart rate after the test. If the heart rate was more than 100 before the test, it was taken out of the test and the next day the heart rate was checked again. This test was performed in a 30-meter round trip for six minutes and the distance traveled for six minutes was interpreted as the test result. Also, the heart rate after the test according to the equation was used to calculate the maximum aerobic capacity. To perform a step test using a step proportional to the person's height, which is done at a rate of 96 pulses per minute or 24 times climbing the step, and after the end of three minutes, the person immediately sits and the doctor counts the heart rate per minute after 15 seconds. The maximum aerobic capacity was calculated according to the formula. Interpretation of tests was done based on the existing criteria by the occupational medicine assistant and under the supervision of the supervisor. Then, based on the purposes of the research, a checklist of personal information and tests information including gender - age - height - weight - blood pressure - history of disease - history of drug use - heart rate at rest before the test - heart rate after test - shortness of breath - fatigue - spo2 - chest pain - dizziness - lower limb pain and distance completed within 6 minutes for each person. The obtained information was entered into SPSS software version 25 and the data were analyzed. Written consent was received from all participants in the study and the study project was approved by the ethics committee of Hormozgan University of Medical Sciences with the code IR.HUMS.REC.1399.480.

**RESULTS**

Data were analysed for 90 patients referred to the Occupational Medicine Clinic of Shahid Mohammadi Hospital in Bandar Abbas who performed a step test and a 6-minute walk on two different days. Of the 90 cases studied, 45 were in the age group of 22 to 27 years, 31 were in the age group of 28 to 32 years and 14 were in the age group of 33 to 38 years. Of the 90 cases studied, 28 were in the weight group of 60 to 70 kg, 45 were in the weight group of 71 to 80 kg and 17 were in the weight group of 81 to 90 kg. In the step test group, out of 90 cases studied, 48 were in the first group with a heart rate of 150 to 160, 51 in the second group with a heart rate of 161 to 170 and 2 in the third group with a heart rate above 170. Also in the 6-minute walk group
from 90 cases studied, 18 people were in the first group with a heart rate of 96 to 110, 51 people in the second group with a heart rate of 111 to 120 and 31 people in the third group with a heart rate above 120.

In the step test group, the mean and standard deviation of maximum oxygen consumption, age, weight and heart rate were $42.28 \pm 2.74$, $27.95 \pm 3.83$, $74.13 \pm 7.23$ and $161.81 \pm 5.17$, respectively. Also in the 6-minute walk group, the mean and standard deviation of maximum oxygen consumption, age, weight and heart rate were $41.19 \pm 3.11$, $27.95 \pm 3.83$, $74.13 \pm 7.23$, $116.73 \pm 6.61$ respectively (Table 1).

**Table 1. Descriptive statistics of the research variables in two groups**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Variable</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three minutes step test</td>
<td>Vo2max</td>
<td>36.57</td>
<td>49.17</td>
<td>42.28</td>
<td>2.74</td>
<td>90</td>
</tr>
<tr>
<td>Age</td>
<td>22</td>
<td>38</td>
<td>27.95</td>
<td>3.83</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>60</td>
<td>91</td>
<td>74.13</td>
<td>7.23</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>150</td>
<td>174</td>
<td>161.81</td>
<td>5.17</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Six minutes’ walk test</td>
<td>Vo2max</td>
<td>32.70</td>
<td>46.31</td>
<td>41.19</td>
<td>3.11</td>
<td>90</td>
</tr>
<tr>
<td>Age</td>
<td>22</td>
<td>38</td>
<td>27.95</td>
<td>3.83</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>60</td>
<td>91</td>
<td>74.13</td>
<td>7.23</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>96</td>
<td>128</td>
<td>116.73</td>
<td>6.61</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

The correlation coefficient between maximum oxygen consumption and age, weight and heart rate in the step test group was -.28, -.54 and -.80, respectively. Also, the correlation coefficient between maximum oxygen consumption and age, weight and heart rate in the 6-minute walk group was -.41, -.83 and -.51, respectively. All coefficients obtained at the level of 0.001 are significant (Table 2).

**Table 2. Correlation matrix of study variables in the two groups**

<table>
<thead>
<tr>
<th>Groups</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>Weight</td>
</tr>
<tr>
<td>Three minutes step test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.28</td>
<td>-.54</td>
</tr>
<tr>
<td>p</td>
<td>.001</td>
<td>.001</td>
</tr>
<tr>
<td>Six minutes’ walk test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.41</td>
<td>-.83</td>
</tr>
<tr>
<td>p</td>
<td>.001</td>
<td>.001</td>
</tr>
</tbody>
</table>
In Table 3, the results of the regression equation for the two groups are presented. In the model of the 3-minute step test group, 78% of the variance of $v_{o2max}$ is explained by the variables of age, weight, and heart rate. Also, in the 6-minute walk group model, 70.6% of the variance of $v_{o2max}$ was explained by the variables of age, weight, and heart rate. The results show that the 6-minute walk test, similar to the 3-minute step test, has an acceptable validity for predicting maximum oxygen consumption and there is no difference between the two methods. Therefore, the 6-minute walk method can be an alternative for the 3-minute step test method. The prediction equations of both methods are presented below. In the new referral cases, based on the following formula and having the values of heart rate, weight, and age, the maximum oxygen consumption can be predicted in either method.

3MST: $VO_{2max} = 82.17 + (-0.26) \times HR + (-0.66) \times weight + (-0.023) \times age$

6MWT: $VO_{2max} = 109.83 + (-0.68) \times HR + (-0.28) \times weight + (-0.021) \times age$

<table>
<thead>
<tr>
<th>Groups</th>
<th>Adjusted $R^2$</th>
<th>F</th>
<th>P</th>
<th>Constant</th>
<th>Heart rate</th>
<th>Weight</th>
<th>Age</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three minutes step test</td>
<td>.78</td>
<td>106.28</td>
<td>.05</td>
<td>82.17</td>
<td>-.26</td>
<td>-.66</td>
<td>-.23</td>
<td>.05</td>
</tr>
<tr>
<td>Six minutes’ walk test</td>
<td>.71</td>
<td>72.18</td>
<td>.05</td>
<td>109.83</td>
<td>-.68</td>
<td>-.28</td>
<td>-.21</td>
<td>.05</td>
</tr>
</tbody>
</table>

In figure 1, the maximum oxygen consumption in terms of the distance traveled in the six-minute walk test is presented. According to the diagram below, the greater the distance traveled, the maximum oxygen consumption increases. The equation for predicting maximum oxygen consumption in terms of distance is also presented below. According to the following equation, based on the amount of distance traveled by new clients, their maximum oxygen consumption can be predicted: $VO_{2max} = 0.06 \times Distance + 8.5$
DISCUSSION

It is now believed that the ability to perform physical work should be determined using the maximum aerobic capacity or maximum oxygen consumption [1]. By definition, maximal aerobic capacity is the maximum amount of oxygen per liter that can be absorbed by the respiratory tract per unit of time per minute and delivered to the working muscles through the blood. Many researchers have set an acceptable limit for a workload of eight hours, and believe that the average effort during work should not be exceeded. Thus, the maximum amount of oxygen that the respiratory system and human circulatory system can transfer is determined by the capacity to perform physical work, and therefore measuring and determining the factors affecting it is of particular importance and value in establishing the physiological fit of the worker with the work [11].

In a study performed on 90 men referred to the occupational medicine clinic of Shahid Mohammadi Hospital in Bandar Abbas in 2020, a descriptive-analytical cross-sectional study was used to validate a six-minute walk test to estimate the Vo2max in healthy individuals. To determine the Vo2max in healthy individuals based on the step test, 78% of the variance of maximum oxygen consumption was explained by weight, age and heart rate variables, and also
to determine the Vo2max in healthy individuals based on the 6-minute walk test 70.6% of the variance of maximum oxygen consumption was explained by weight, age and heart rate variables.

These results showed that the six-minute walk test similar to the step test has an acceptable validity for predicting maximum oxygen consumption and there is no difference between the two methods. Therefore, it can be said that the 6-minute walk method can be a good alternative to the step method. In a systematic study by Moore & Barker [12] on the validity and reliability of the four square step test in different adult populations, the results revealed that three of the studies were of moderate methodological quality scoring low in risk of bias and applicability for all domains in the QUADAS-2 tool. Three studies scored “fair” on the COSMIN four-point checklist for the reliability components. The concurrent validity of the FSST was measured in nine of the studies with moderate to strong correlations being found. Excellent Intra class Correlation Coefficients were found between physiotherapists carrying out the tests (ICC = .99) with good to excellent test-retest reliability shown in nine of the studies (ICC = .73–.98).

In a study conducted by Lee [7] on the validation of the 6-minute walk test and the cardiopulmonary fitness test in type 2 diabetic patients, the average distance traveled during the 6-minute walk test was 54 ± 53.8 meters and the average heart rate was 93 ± 11 beats per minute after the step test. Regression equations were constructed to predict Vo2max based on distance traveled, age, height, weight, blood sugar, and HbA1c during the 6-minute walk and step test, and it was concluded that both of the 6-minute walk and step test was reliable and valid. In a study by Hong et al. [8], they validated step test and 6-minute walk test in healthy young people and concluded that both 20 and 30 cm step tests were valid for estimating Vo2max. Also, their study on estimating the Vo2max was confirmed by a 6-minute walk test, and the Vo2max in the 6-minute walking test was valid and ranged from .77 to .91.

As shown in the study, this can be achieved by estimating the Vo2max of individuals to assess workers' health and health promotion and also to evaluate their working capacity through various methods.

Based on the current study findings, it is suggested that the future studies be performed with a larger number of people or for a longer period of time, in different sex groups or in different patients, in order to comprehensively study the subject. A suitable place for examinations,
especially tests to assess the physical ability of the person, where there is freedom of action to perform a variety of methods is recommended.

**LIMITATIONS**
Temperature and humidity conditions outside the ward affect a person's ability. Covid-19 pandemic and infection and hospitalization history caused the person to be excluded from the study.

**ETHICAL CONSIDERATION**
This study has ethical approval number IR.HUMS.REC.1399.480 from Hormozgan University of Medical Sciences.

**CONFLICT OF INTEREST**
There is no conflict of interest for the authors.

**FINANCIAL SUPPORT**
All article costs are sponsored by the authors.

**REFERENCES**


