OXYGEN UPTAKE DURING MAXIMAL 
BY THREE AEROBIC METHODS 
( A COMPARATIVE STUDY ) 

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Abstract 

The purpose of this research was to compare the maximum oxygen uptake obtained by the ergometer bicycle, the treadmill and the twelve minute run-walk test. Fifteen healthy students were selected to participate in this study. After a familiarization and practice session each subject was randomly tested using the ergometer, the treadmill and the twelve minute run. Tests took place at the laboratory of the Department of Physical Education, Yarmouk University. The analysis of variance utilized in this study revealed no significant difference between the three tests (α .01 and α .05). The reliability and feasibility of Cooper's twelve minute run test was substantiated in this study.

It is generally agreed that the most common method of estimating physical fitness is to measure oxygen consumption (maximal oxygen uptake) related to different types of exercises. Maximal oxygen uptake (VO₂ max) is defined as the greatest rate at which oxygen can be consumed during exercise at sea level (AAHPERD, 1984). It is typically expressed as milliliters of oxygen consumed per kilogram of body weight per minute.

It is agreed upon that tests to measure the maximal oxygen uptake involve a progressive increase in work usually performed on a bicycle ergometer or treadmill or running to the point at which further increments of work are accompanied by a plateau, decrease or slight increase in the oxygen consumption (McArdle and Magel, 1970; Saltin and Astrand, 1967; Taylor and Buskirk, 1955).

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In assessing the review of previous literature for this particular study, the following information was obtained. Several studies have determined the relationship between VO$_2$ max expressed in ml/kg/min obtained from treadmill test and the twelve minute run. Cooper (1968) tested 115 U.S Air Force men age 17-52 finding a correlation coefficient of 0.90. Astrand and Rodhal (1977) summarised the mean values of several studies that compare running on the treadmill and bicycling, and they noted that on the treadmill the oxygen uptake may be bought to near 100% maximum, whereas bicycling only brought oxygen uptake to somewhere between 92% and 96%.

Also of significance was the study of Nagel et al. (1971) where the progressive VO$_2$ test responses for the bicycle, treadmill and step device were found to be unique to the instrument loads used. The bicycle regression values were consistently higher than those of treadmill, and the treadmill values were consistently higher than those of the step device. Glassford et al. (1965) reported values averaging 8% higher for maximal oxygen uptake on the treadmill (inclination 3°) as compared to values performed on the ergometer. A similar study by Hermansen and Saltin (1965) also reported 7% higher oxygen uptake on the treadmill (inclination > 3°) as compared to bicycling of fifty revolutions per minute.

Newton (1963) concluded that the twelve minute run test and the one mile test were valid measures of aerobic working capacity. Burke (1976) also reported that the twelve minute run test had a significantly higher correlation of .90 with VO$_2$ max (ml/kg/min.) than did any of the other tests. He also concluded that the Balke Test had a correlation of .77. with VO$_2$ max and was a significantly stronger measure of aerobic power than any of the other submaximal tests. Burke also indicated that the VO$_2$ max elicited during the bicycle exercise may be affected to a greater extent by weight than in the treadmill running.

Michael and Hackett (1968) reported a higher oxygen uptake during the treadmill run while testing high school students. The highest measure on the bicycle was 1.83 L/min, and the highest measure on the treadmill was 2.21 L/min. In a similar study, Mcardie and Magel (1970) also found a difference of .324 L/min in favor of the treadmill, while measuring the maximum oxygen uptake on the treadmill and bicycle ergometer.
In a study by Michael et al (1969), four male and female subjects were asked to select work loads on the treadmill and the bicycle that would exhaust them if they carried out the exercise for fifteen minutes. These subjects were tested in randomized order using a bicycle one day and a treadmill on another day. By comparing the data of the male and the female, it was seen that both groups had a slightly lower $O_2$ uptake level with the ergometer. The energy cost was always slightly higher with men.

**Purpose of Study:**

The purpose of this study was to compare the maximum oxygen uptake obtained by three aerobic methods:

1. The Bicycle ergometer.
2. The Treadmill.
3. Cooper's test (12m. Run-Walk). Hence, the following null hypothesis will be investigated in this study: There is no difference in oxygen uptake obtained by the bicycle, treadmill and Cooper's twelve minute run-walk test.

**Methodology:**

The subject chosen for this study were fifteen volunteer male athletes from the Department of Physical Education at Yarmouk University between ages 20-23 who exercise regularely and are in good shape. The procedures for the present study consisted of the administration of Cooper's 12 minute run test, bicycle ergometer test and treadmill test. On testing days, only one test was administered to each subject so as not to affect performance on a subsequent test. Before a particular testing session involving the use of respiratory apparatus (ergometer or treadmill), each subject was given a familiarization and practice session in which to become acquainted with the use of the apparatus.

The order of test administration was randomly varied among subjects in an attempt to assess sequential effect (Burke, 1976). Test administration and data collection took place at the laboratory of the Department of Physical Education, Yarmouk University, and it lasted for 3 months.

**Tests:**

1. Cooper's twelve minute run-walk test was performed on a 330 meter outdoor track. After free warm up, participants were instructed to cover as much distance
during the 12 minute period as possible, noting that a constant steady pace would be most effective (Maskud and Couts, 1968). Students ran in groups of five with the number of laps and elapsed time called out frequently. At the end of 12 minutes, the number of laps, to the nearest meter, was recorded. A stop watch was used to monitor the time. VO2 max was estimated by using the formula: (Speed meter / minutes - 133 m/minute) X (.178 ml / kg / min. + 33.3 ml / kg / min.), (Cooper, 1968).

2. Bicycle ergometer test: Maximum oxygen uptake of participants was determined using the Magel (1970) technique. To achieve this, the MGC's 2001 Cardiopulmonary Exercise System and MFE 400 L ergometer were used (photo 1). Air was sampled directly into the MGC's automated gas analysis system. The gas analyser was calibrated using certified gas sample. Heart rates were also monitored continuously with a standard electrocardiographic apparatus (Birchler ECG heart monitor) during the test period.

After adjusting seat height (The seat should be high enough so that the leg is almost completely stretched when the pedal is in its lowest position (Astrand and Rodhal, 1977), and properly fitting the mouth piece, each subject pedaled at a fixed pedal frequency rate of 60 rpm. A quartz metronome was used to insure a steady pace. According to Hermansen and Saltin (1969) this pedaling frequency is apt to elicit the highest maximum VO2. The work was increased 180 kilogram / minute until the subject was unable to continue (Mcardle and Magel, 1970). The plateauing of VO2 during the first stages of the effort, maximum heart rate, and the appearance of each subject were used as criteria for determining maximum effort.

3. Treadmill test: VO2 max of each subject was achieved using the method of Mitchell et al (1958). The Collins Treadmill was used for this purpose (Warren E, Collins). Following a 12 minute submaximal warm up period, the subject was given a series of 3 minute work loads. The treadmill speed was set at 7 mph and was increased by 2.5% grade with each run. Expired air was directly collected by the MGC 2001 gas analyser during the last 30 seconds of each run (photo 2). Only certified gases were used in the analyser. VO2 max was defined as VO2 at which exhaustion occurred or when there was less than 150 ml increase between work loads. To ensure the subject's safety, heart rates were monitored by an EKG during the test period.
Each subject was tested on the ergometer
The analysis of variance (ANOVA) was used in this study to determine statistical differences between the results of the above mentioned three methods of VO2 attainment.
Results and Discussion:

The results compiled from the testing of fifteen students are listed in Table (1). Although no statistical differences between values obtained by the three methods were noted (Table 2), it is apparent that the treadmill measures 8.4% higher than the bicycle ergometer. This result is consistent with the difference of 7-8% reported in other studies (Astrand and Rodhal, 1977; Glassford et al., 1965; and Hermansen and Saltin, 1965). The higher work tempo during running may enhance the venous return. Additionally, when a person runs on the treadmill, he is forced to follow the speed of the belt or jump off, while in the bicycle ergometer it is possible to continue to work at a reduced rate in most types of bicycle ergometer, thus affecting VO$_2$ max (Astrand, Rodhal, 1977).

Cooper's twelve minute run-walk test has a higher value than the bicycle ergometer (4.7%) and a lower value than the treadmill by 3.5% also.

As shown in Table 1, and 2, the twelve minute run test measures the maximum oxygen consumption in a value between the treadmill and the ergometer. However, the twelve minute run test appears to have a lower variability than the other two tests because of its natural and practical procedures. This finding is consistent with Cooper's finding (1968). He explained that the results from the maximum oxygen consumption studies showed a very good correlation with the twelve minute test, indicating that the twelve minute test was a very good substitute for the time consuming but more accurate oxygen consumption tests. Other researchers have concluded that treadmill testing is preferred over bicycle ergometer, because specific muscle development and extensive training are prerequisites to the achievement of maximum performance on a bicycle ergometer (Newton, 1963; Astrand and Saltin, 1961).

Moreover, several studies have determined a relationship between VO$_2$ max expressed in ml/kg/min obtained from a treadmill test and the twelve minute run test. Maksud and Coutts (1967) obtained a correlation coefficient of .65, Cooper (1968) tested 115 "United States Air Force men, finding a correlation coefficient of .90.
Table (1)
Mean and S.D. of VO₂ max values by the three methods

<table>
<thead>
<tr>
<th>Subject</th>
<th>Running test</th>
<th>Treadmill test</th>
<th>Ergometer test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>60.71</td>
<td>62.30</td>
<td>58.74</td>
</tr>
<tr>
<td>2.</td>
<td>58.12</td>
<td>60.43</td>
<td>56.35</td>
</tr>
<tr>
<td>3.</td>
<td>54.79</td>
<td>56.26</td>
<td>52.11</td>
</tr>
<tr>
<td>4.</td>
<td>53.66</td>
<td>54.25</td>
<td>50.29</td>
</tr>
<tr>
<td>5.</td>
<td>47.31</td>
<td>49.35</td>
<td>45.66</td>
</tr>
<tr>
<td>6.</td>
<td>57.10</td>
<td>58.65</td>
<td>53.44</td>
</tr>
<tr>
<td>7.</td>
<td>46.21</td>
<td>46.71</td>
<td>45.81</td>
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<tr>
<td>8.</td>
<td>46.20</td>
<td>48.22</td>
<td>43.33</td>
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<td>9.</td>
<td>45.70</td>
<td>47.41</td>
<td>43.41</td>
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<td>10.</td>
<td>43.51</td>
<td>46.21</td>
<td>40.23</td>
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<tr>
<td>11.</td>
<td>48.91</td>
<td>50.65</td>
<td>49.01</td>
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<td>12.</td>
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<td>52.50</td>
<td>49.33</td>
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<td>13.</td>
<td>41.01</td>
<td>44.65</td>
<td>39.88</td>
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<td>14.</td>
<td>56.63</td>
<td>57.32</td>
<td>52.60</td>
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<tr>
<td>15.</td>
<td>45.18</td>
<td>47.36</td>
<td>41.18</td>
</tr>
<tr>
<td>X</td>
<td>50.38</td>
<td>52.15</td>
<td>48.09</td>
</tr>
<tr>
<td>SD</td>
<td>6.04</td>
<td>5.69</td>
<td>5.89</td>
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</table>

Table (2)
Summary Anova of three methods

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Fcv</th>
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</thead>
<tbody>
<tr>
<td>Between</td>
<td>124.19</td>
<td>2</td>
<td>62.09</td>
<td>1.77</td>
<td>3.25 (α .05)</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.18 (α .01)</td>
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<tr>
<td>Within</td>
<td>1470.12</td>
<td>42</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1594.31</td>
<td>44</td>
<td></td>
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</tbody>
</table>
Conclusion:

In conclusion, the findings of this study substantiate the administrative feasibility and reliability of the twelve minute run-walk test in comparison with the more expensive techniques. The twelve minute run test offers easier and more natural procedure for researchers and subjects; it has more practicability, and can be used for a large group at one time, with minimal equipment.

Recommendation:

It is recomended that findings of this study be compared to the findings of other studies which utilize other maximum oxygen uptake attainment methods. Additionally recruitment of larger samples will be of vital importance.
References


