A comparative study of maximal oxygen consumption (VO$_{2\text{max}}$) determined by two sub-maximal exercise tests

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Abstract
Aim: The aim of the study was to compare the predictive values of VO$_{2\text{max}}$ determined by two sub-maximal exercise tests: Bruce sub-maximal exercise test and Treadmill jogging test and to find correlation between these two tests.

Materials and Methods: One hundred twenty five apparently healthy male subjects 18-25 years underwent first three stages of the original Bruce protocol in one session and exercise according to Treadmill jogging test in another session in randomised order. VO$_{2\text{max}}$ was calculated by using appropriate regression equation.

Results: VO$_{2\text{max}}$ values from two tests (t test) revealed similar mean values of VO$_{2\text{max}}$ between the two tests (47.06 ± 2.74 vs. 47.20 ± 2.27, t=0.64; p=0.649) i.e. not differed statistically. Concordance correlation coefficient showed an insignificant (p>0.05) concordance between the two tests (r=0.020, 95% CI=-0.152 to 0.191) with low precision (p=0.021) but with high bias correction factor (Cb=0.98).

Conclusion: In conclusion we can say that these two tests are comparable in terms of mean values of VO$_{2\text{max}}$. Poor correlation coefficient between the two tests should be subjected to further study with subjects having wider age range and wide range in VO$_{2\text{max}}$ values.

Keywords: VO$_{2\text{max}}$, Sub-maximal exercise, Treadmill test, Physical fitness.

Introduction
Fitness is the ability of the individual to maintain various internal equilibria as closely as possible to the resting state during strenuous exercise and to return back to baseline state promptly after cessation of activity.更高的 levels of physical fitness appear to delay all-cause mortality primarily due to lowered rates of cardio-vascular diseases and cancer. Cardiorespiratory fitness is a health-related component of physical fitness defined as the ability of the circulatory, respiratory, and muscular systems to supply oxygen during sustained physical activity.

Cardiorespiratory fitness is usually expressed in metabolic equivalents (METs) or maximal oxygen consumption (VO$_{2\text{max}}$) measured by exercise tests such as treadmill or cycle ergometer. VO$_{2\text{max}}$ is internationally accepted parameter & is the first choice in measuring a person’s cardiopulmonary status. Those who are more fit have higher VO$_{2\text{max}}$ and can exercise more intensely and longer than those who are not as well conditioned.

Direct measurement of VO$_{2\text{max}}$ is restricted within a well equipped laboratory because of its exhausting, cumbersome, hazardous, complicated, expensive, the time spent to measure it and standardization. Moreover it requires maximal exertion and is not advisable for compromised and debilitating advancing cardio-respiratory individuals.

Sub-maximal test are similar to a VO$_{2\text{max}}$ test, but do not reach the maximum of the respiratory and cardio-vascular systems. In Sub-maximal test, extrapolation is used to estimate maximal capacity. Although it may be efficacious to use an exercise test requiring maximal efforts in young fit and willing participants, sub-maximal exercise tests, which are relatively safer requires less time, are practical in a variety of settings. Sub-maximal exercise testing provides administrator an opportunity to observe responses to exercise and to teach participants the selection of an appropriate intensity of exercise.

Earlier studies have validated various sub-maximal exercise test protocols for indirect determination of VO$_{2\text{max}}$.

So the present study was designed to predict the values of VO$_{2\text{max}}$ by two sub-maximal exercise tests (Bruce sub-maximal exercise test and Treadmill jogging test) and also to find correlation between these two tests.

Materials and Methods
One hundred twenty five apparently healthy male subjects were selected for the study after applying inclusion and exclusion criteria.

Inclusion Criteria: Apparently healthy male subjects between 18 to 25 years of age, BMI between 18.5 and 25.0 kg/m$^2$, pre-exercise BP <140/90 mmHg and having a normal pre-exercise ECG were included in the study.

In addition subjects had to fill a Physical Activity Readiness (PAR-Q) Form before exercise. Subjects
who had answered NO to all the questions were selected for the study.

**Exclusion Criteria:** Subjects with history suggestive of cardio-vascular, respiratory, metabolic, musculo-skeletal and emotional disorders were excluded.

**Evaluation:** Informed written consent was taken from all the subjects. The study was approved by the Institutional Ethical Committee (IEC).

Subjects were divided into small groups and then they were familiarized with the instruments. Experimental protocols were explained to them in detail. They were also given a trial run on treadmill to relieve the anxiety related to the treadmill running during actual testing and data collection. For treadmill testing guidelines from American College of Sports Medicine (ACSM) were followed.

Height, weight, pre-exercise blood pressure and pre-exercise ECG were measured following standard procedures.

PC Based Stress Test Analysis (Stress-INVX1) system (CARDIVISION Exercise Stress Test System and Rest ECG Analysis System) was used for treadmill testing.

**Protocols**

**Bruce Sub-maximal Exercise Test**

In this test subject performs first two or three stages of the original Bruce protocol. Heart rate, BP and RPE were recorded for each stage.

VO$_2$\textsuperscript{max} is then calculated by the ACSM equation utilising steady state heart rate form stage 2 and stage 3.

\[
\text{VO}_2\text{\textsuperscript{max}} \, [\text{ml/kg/min}] = m \times (\text{HRmax-HR2}) + VO_2\text{\textsuperscript{max}}
\]

Where

\[
m = \left[ \frac{\text{VO}_2 - \text{VO}_2\text{\textsuperscript{max}}} {\text{HR2-HR1}} \right]
\]

\[
\text{VO}_2\text{\textsuperscript{max}} = \text{sub-max VO}_2\, [\text{ml/kg/min}] \, \text{from stage 1} = [0.1 \times \text{speed}] + [1.8 \times \text{speed} \times \%\text{grade}] + 3.5
\]

\[
\text{VO}_2\text{\textsuperscript{max}} = \text{sub-max VO}_2\, [\text{ml/kg/min}] \, \text{from stage 2} = [0.1 \times \text{speed}] + [1.8 \times \text{speed} \times \%\text{grade}] + 3.5
\]

\[
\text{HR1} = \text{HR steady state [BPM]} \, \text{from stage 1 that counts HRmax = 220-age.}
\]

\[
\text{Speed in m/min [to convert mph to m/min multiply by 26.82].}
\]

\[
\% \text{ grade} = \text{elevation from ground in degrees divided by 100.}
\]

**Treadmill Jogging Test:** In this test subjects were made to walk at brisk walking speed at zero level grade for three minutes. This is followed by jogging at a sub-maximal jogging speed between 4.3 and 7.5 mph at zero level grade until a steady state HR (two consecutive HR within 3 BPM 30 sec apart) was achieved. Heart rate, BP and RPE were recorded for walking and then for jogging stage.

The following equation was used to predict VO$_2$\textsuperscript{max}.

\[
\text{VO}_2\text{\textsuperscript{max}} = 54.07 + 7.062 \times \text{gender} \, [\text{male}=1, \text{female} = 0] -0.1938 \times \text{Weight [kg]} + 4.47 \times \text{speed [mph]} -0.1453 \times \text{heart rate [BPM]}
\]

**Statistical Analysis**

Data were summarized as Mean ± SD (standard deviation). Concordance correlation coefficient (precision p and bias correction factor Cb) analysis was used to assess the agreement between two tests. A two-tailed (α=2) p value less than 0.05 (p<0.05) was considered statistically significant. Analyses were performed on SPSS software (PSAW, Windows version 18.0).

**Results**

The age, Ht, Wt and BMI of all subjects ranged from 18 to 25yrs, 162-187 cm, 51-79 kg and 18.17 to 25.06 kg/m$^2$ respectively with mean (± SD) 21.17 ± 1.98 yrs, 172.26 ± 4.62 cm, 64.42 ± 6.19 kg and 21.70 ± 1.79 kg/m$^2$ respectively.

The values of VO$_2$\textsuperscript{max} in Bruce sub-maximal exercise test and Treadmill jogging test ranged from 42.07 to 58.23 ml/kg/min and 40.51 to 51.17 ml/kg/min respectively with mean (± SD) 47.06 ± 2.74 ml/kg/min and 47.20 ± 2.27 ml/kg/min respectively.

Comparing the mean values of VO$_2$\textsuperscript{max}, t test revealed similar VO$_2$\textsuperscript{max} between the two tests (47.06 ± 2.74 vs. 47.20 ± 2.27, t=0.64; p=0.649) i.e. not differed statistically.

Further, to see the comparability of VO$_2$\textsuperscript{max} estimated from two tests, concordance correlation coefficient was evaluated and summarized in Table 2. Table 2 showed an insignificant (p>0.05) concordance between the two tests (r=0.020, 95% CI=-0.152 to 0.191) with low precision (p=0.021) but with high bias correction factor (Cb=0.98).

**Table 1:** Comparisons of estimated VO$_2$\textsuperscript{max} (Mean ± SD, n=125) of subjects from two different tests

<table>
<thead>
<tr>
<th>Bruce submaximal exercise</th>
<th>Treadmill jogging</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.06 ± 2.74</td>
<td>47.20 ± 2.27</td>
<td>0.46</td>
<td>0.649</td>
</tr>
</tbody>
</table>

**Table 2:** Comparability of VO$_2$\textsuperscript{max} estimated from two tests using concordance correlation coefficient analysis

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concordance correlation coefficient (r)</td>
<td>0.020</td>
</tr>
<tr>
<td>95% CI</td>
<td>-0.152 to 0.191</td>
</tr>
<tr>
<td>Pearson p (precision)</td>
<td>0.021</td>
</tr>
<tr>
<td>Bias correction factor (Cb)</td>
<td>0.981</td>
</tr>
</tbody>
</table>
In conclusion we can say that either of the tests can be used to calculate \( \text{VO}_{2\text{max}} \) values.

The same protocol should be taken for follow up of the \( \text{VO}_{2\text{max}} \) values as required in endurance training, sports settings etc.

The choice of the testing protocol should be given to the subject.

Subjects with low initial fitness can be tested by Treadmill jogging tests as simply reducing the speed of treadmill will also reduce workload on Cardio-vascular system.

References


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