

## A comparative study of maximal oxygen consumption (VO<sub>2</sub>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<sub>2</sub>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<sub>2</sub>max was calculated by using appropriate regression equation.

**Results:** VO<sub>2</sub>max values from two tests (t test) revealed similar mean values of VO<sub>2</sub>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<sub>2</sub>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<sub>2</sub>max values.

**Keywords:** VO<sub>2</sub>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.<sup>1</sup> Higher levels of physical fitness appear to delay all-cause mortality primarily due to lowered rates of cardio-vascular diseases and cancer.<sup>2</sup> Cardio-respiratory 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.

Cardio-respiratory fitness is usually expressed in metabolic equivalents (METs) or maximal oxygen consumption (VO<sub>2</sub>max) measured by exercise tests such as treadmill or cycle ergometer. VO<sub>2</sub>max is internationally accepted parameter & is the first choice in measuring a person's cardiopulmonary status.<sup>3</sup> Those who are more fit have higher VO<sub>2</sub>max and can exercise more intensely and longer than those who are not as well conditioned.

Direct measurement of VO<sub>2</sub>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<sub>2</sub>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<sub>2</sub>max.

So the present study was designed to predict the values of VO<sub>2</sub>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<sup>2</sup>, 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)<sup>4</sup> 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 than 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.<sup>5</sup> 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<sup>6</sup>

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.

$VO_{2max}$  is then calculated by the ACSM equation utilising steady state heart rate from stage 2 and stage 3.

$$VO_{2max} [ml/kg/min] = m [HR_{max}-HR_2] + VO_{2}$$

Where

$$m = [VO_{22} - VO_{21}] / [HR_2 - HR_1]$$

$VO_{21}$  = sub-max  $VO_2$  [ml/kg/min] from stage 1

$$= [0.1 \times \text{speed}] + [1.8 \times \text{speed} \times \% \text{grade}] + 3.5$$

$VO_{22}$  = sub-max  $VO_2$  [ml/kg/min] from stage 2

$$= [0.1 \times \text{speed}] + [1.8 \times \text{speed} \times \% \text{grade}] + 3.5$$

$HR_1$  = HR steady state [BPM] from stage 1 that counts

$HR_2$  = HR steady state [BPM] from stage 2 that counts

$HR_{max}$  = 220-age.

Speed in m/min [to convert mph to m/min multiply by 26.82].

% grade = elevation from ground in degrees divided by 100.

**Treadmill Jogging Test:**<sup>7</sup> 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 than for jogging stage.

The following equation was used to predict  $VO_{2max}$ .

$$VO_{2max} = 54.07 + 7.062 \times \text{gender} [\text{male} = 1, \text{female} = 0] - 0.1938 \times \text{Weight} [\text{kg}] + 4.47 \times \text{speed} [\text{mph}] - 0.1453 \times \text{heart rate} [\text{BPM}]$$

## Statistical Analysis

Data were summarized as Mean  $\pm$  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 ( $\alpha=2$ ) 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<sup>2</sup> respectively with mean ( $\pm$  SD) 21.17  $\pm$  1.98 yrs, 172.26  $\pm$  4.62 cm, 64.42  $\pm$  6.19 kg and 21.70  $\pm$  1.79 kg/m<sup>2</sup> respectively.

The values of  $VO_{2max}$  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 ( $\pm$  SD) 47.06  $\pm$  2.74 ml/kg/min and 47.20  $\pm$  2.27 ml/kg/min respectively.

Comparing the mean values of  $VO_{2max}$ , t test revealed similar  $VO_{2max}$  between the two tests (47.06  $\pm$  2.74 vs. 47.20  $\pm$  2.27,  $t=0.64$ ;  $p=0.649$ ) i.e. not differed statistically.

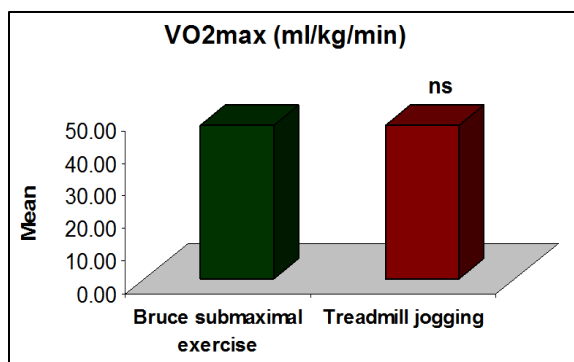
Further, to see the comparability of  $VO_{2max}$  estimated from two tests, concordance correlation coefficient was evaluated and summarized in Table 2. Table 2 showed an insignificant ( $p > 0.05$ ) concordance between the two tests ( $r=0.020$ , 95% CI=-0.152 to 0.191) with low precision ( $p=0.021$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

**Table 1: Comparisons of estimated  $VO_{2max}$  (Mean  $\pm$  SD, n=125) of subjects from two different tests**

Bruce submaximal exercise	Treadmill jogging	t value	p value
47.06 $\pm$ 2.74	47.20 $\pm$ 2.27	0.46	0.649

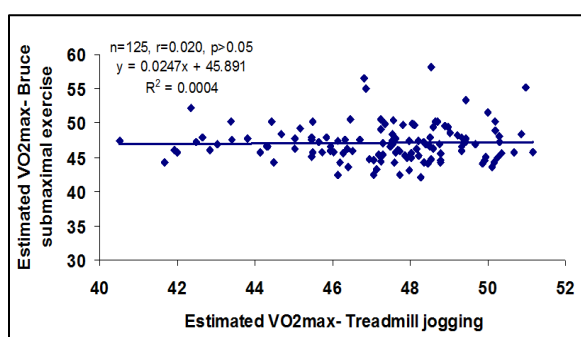
**Table 2: Comparability of  $VO_{2max}$  estimated from two tests using concordance correlation coefficient analysis**

Characteristics	Statistics
Concordance correlation coefficient (r)	0.020
95% CI	-0.152 to 0.191
Pearson p (precision)	0.021
Bias correction factor (Cb)	0.981



<sup>ns</sup>p>0.05- as compared to Bruce submaximal exercise

**Fig. 1. Comparisons of estimated mean VO<sub>2</sub>max between two tests**



**Fig. 2: Correlation of VO<sub>2</sub>max estimated from two tests**

## Discussion

The importance of physical fitness cannot be emphasized enough. Everyday advancements in the technology are dragging us towards more sedentary lifestyle. The total amount of physical activity carried out by an individual is decreasing in amount day by day. Long standing decrease in physical activity is leading to more increase in the incidence and prevalence of the lifestyle diseases. Those who are fit require physical activity to maintain their fitness and those who are currently unfit also require physical activity to increase their level of physical fitness.

The VO<sub>2</sub>max values in our present study when compared with VO<sub>2</sub>max values of other studies such as 48.74±8.74 ml/kg/min by Koley S.<sup>8</sup> [2007], 51.21 ± 7.20 ml/kg/min in north Indian vs. 49.19 ± 7.86 ml/kg/min in south Indian subjects by Smilee JS et al<sup>9</sup> [2010] and 48.90 ± 4.24 ml/kg/min by Setty P et al.<sup>10</sup> [2013] were found. These differences in values of VO<sub>2</sub>max may be apparent because all the tests are indirect and a small difference can be there due small error in prediction. They may be actual due to difference in fitness or genetic or socioeconomic or multi-factorial in nature.

We found mean values of VO<sub>2</sub>max predicted by two tests to be comparable. In our present study low correlation coefficient arise probably due to less variation in age which is also described as a factor for

low correlation coefficient by Grant S et al.<sup>11</sup> [1995]. Another reason for low correlation coefficient appears to be low range of VO<sub>2</sub>max value in each test which is also described as a factor for low correlation coefficient by Grant JA et al.<sup>12</sup> [1999]. The small error in prediction might have added up to give poorer correlations.

Whether less variance in age, narrow range of VO<sub>2</sub>max values in each test and sub-maximal prediction error have resulted in poorer correlations or it is actually a poor correlation should be subjected to future study.

## Conclusion

In conclusion we can say that either of the tests can be used to calculate VO<sub>2</sub>max values.

The same protocol should be taken for follow up of the VO<sub>2</sub>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.

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