Indian J Physiol Pharmacol 2013; 57(2) : 87–94

VO_2 MAX IN AN INDIAN POPULATION : A STUDY TO UNDERSTAND THE ROLE OF FACTORS DETERMINING VO_2 MAX

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(Received on June 11, 2012)

Abstract : VO_2 max is the maximum amount of oxygen a person can consume and the value does not change despite an increase in workload. There is lack of data evaluating the impact of factors, which could affect VO_2 max measurement, particularly in Indian population. The objectives of the present study were (i) to estimate VO_2 max in a young healthy Indian population and to compare it with available prediction equations for Indian population (ii) to correlate time to achieve VO_2 max with the relative VO_2 max (iii) to assess the factors affecting the time to achieve VO_2 max measurement (body composition and physical activity level). Twenty healthy adult males (18-30 years) underwent detailed anthropometry, physical activity level and modified Bruce protocol for VO_2 max assessment. Breath by breath VO_2, VCO_2, oxygen saturation, heart rate, blood pressure were measured continuously and following exercise protocol. There was an internal validity between the estimated VO_2 max and the maximum heart rate (MHR) ($r=0.51$, $P<0.05$). Respiratory rate and tidal volume significantly correlated with VO_2 max $P<0.01$). Linear regression analysis indicated physical activity level (PAL) was a strong predictor of time to reach VO_2 max. Out of the 3 prediction equations computed to estimate VO_2 max, 2 equations significantly overestimated VO_2 max. In Conclusion, physical activity level emerged to be a strong predictor of time to VO_2 max. Time to achieve VO_2 max is an important factor to be considered when determining VO_2 max. There was an overestimation in the VO_2 max values derived from predicted equations.

Key words : VO_2 max, adults, time VO_2, factors, physical activity

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INTRODUCTION

VO_2 max is the maximum amount of oxygen a person can intake and the value does not change despite an increase in workload over time period. VO_2 max is expressed as liters/min as an absolute value or in milliliters/kg/min as relative VO_2 max. VO_2 max is used to assess cardiopulmonary limits during exercise testing and to understand the mechanisms of exercise tolerance. It provides indices of the functional reserve of the organ systems involved and limitations that can be encountered at peak exercise (1, 2).

Of late clinical implication of estimation of VO_2 max has been increasingly recognized (3). VO_2 max estimation is not only used in sport medicine but also of late in life style intervention programmes (4). However, inspite of its utility there has been lack of data particularly in healthy Indian population. Even the small body of data available have performed comparison with the western population and not measured the actual VO_2 max. VO_2 max often used as marker of physical fitness; for the physically inactive men the most accurate prediction model included age, weight, respiratory exchange ratio and tidal volume (5). Responses are also different in children to adult population; young to old; men to women (6). Significant association between physical activity levels derived from questionnaire and direct estimation of VO_2 max have been demonstrated (7). However, there is lack of data of such a relation in an Indian population.

VO_2 max often estimated using prediction equations rather than direct measurement as it is cost effective and relatively easier. This is true if the available prediction equations have been derived in a larger population and compared it against the gold standard. There is lack of studies comparing measured vs predicted VO_2 max in an Indian population.

While estimating VO_2 max, time to achieve VO_2 max has been least explored and instead time to exhaustion is considered as one of the criteria to confirm attainment of VO_2 max (8). There is a lag between the 2 time points. Time to achieve VO_2 max might be a better marker than exhaustion reported by subjects.

Objectives of the present study were, (i) to estimate VO_2 max in healthy Indian population and to compare measured VO_2 max with VO_2 max obtained by prediction equations in Indian population (ii) to correlate time to achieve VO_2 max with the relative VO_2 max values (iii) to assess the factors which affect the time to achieve VO_2 max including weight, percentage fat, fat free mass and physical activity levels.

METHODS

Twenty young healthy male subjects aged between 18-30 years were recruited for the study from in and around the campus. Subjects were included following detailed medical history and clinical examination. Presence of any chronic disease like diabetes, hypertension, tuberculosis, etc, alcohol intake greater than 2 STD per day or any cardiovascular abnormality or respiratory diseases served as the exclusion criteria. All subjects underwent detailed anthropometric measurements. The measured parameters

were height, weight, waist and hip circumferences and skin folds (triceps, biceps, subscapular and suprailliac). The derived parameters included percent fat, fat mass and fat free mass. Following which a physical activity questionnaire was administered (9). A composite index of the level of activity was computed as the physical activity level (PAL), which is the 24 h energy expenditure divided by the estimated basal metabolic rate. PAL cutoff values for grades of physical activity have been derived previously:1.4, sedentary; 1.55 moderately active; 1.75, very active (9). All participants provided their written informed consent to take part in the study, which was approved by the Institution Ethics Review Board.

The protocol was performed 3 hours postprandially. Subjects were instrumented with breath to breath analyzer and pulse oximeter. The protocol followed was the modified Bruce treadmill protocol (10). The protocol had 10 stages with each stage lasting for the duration of 3 minutes. The degree of inclination was changed by 2 degrees before the start of a new stage except for the last 3 stages due to technical limitations. The speed was also increased before the start of a new stage. Throughout the experiment VO_2, respiratory rate, tidal volume, inspired and expired CO_2 and energy expenditure were recorded using MetaMax (CORTEX Biophysik Gmbh, Leipzig, Germany). Heart rate and oxygen saturation were recorded manually every 10 seconds (Welch Allyn Pulse Oximeter, New york, USA). The protocol was stopped once the subject completed all the stages or complained of exhaustion and could not continue any further which was rated using Borg visual analog scale of rate of perceived exertion (RPE). When the subject gave a rating of 8-10 in Borg visual analog scale of RPE, protocol was stopped (11). All parameters continued to be recorded with the subject in sitting position during recovery for a period of 5 minutes.

Following predicted equations were compared with estimated VO_2 max: Equation 1 : VO_2 Max= (0.046*Weight in Kgs)-0.012 (12) ; Equation 2 : VO_2 Max= (0.04*Weight in kgs)+0.232 (13); Equation 3 : VO_2 Max= (0. 018*Weight in kgs)+1.212 (14).

Statistical analysis

Data was examined for normality. Internal validity of parameters of maximal heart rate, respiratory rate, tidal volume, energy expenditure were checked using Pearson/Spearman correlation. Measured VO_2 max was compared with predicted values using Bland Altman plots and compared using paired 't' test. Multiple linear regression was used to assess the association of factors including BMI, fat free mass and physical activity level with time to achieve VO_2 max. Time to exhaustion and time to achieve VO_2 max were compared using paired t test/ Wilcoxon Rank t test. Statistical significance was set at $P<0.05$.

RESULT

Subjects were with mean age 20±0.6 years and were of mean body mass index of 21.6±2.3 kg/m^2. The physical activity level of 90% of the subjects was moderate and two subjects had vigorous physical activity with PAL of 1.99 and 2.12. The VO_2 max ranged from 1.25 to 3.25 L/min. However, the relative VO_2 max, which is often used in

Table I: Descriptive characteristics.

Parameters	*Study group*
Age (yr)	20±0.6
Height (cm)	172.6±5.1
Weight (kg)	64.5±8.8
BMI (kg/m^2)	21.6±2.2
Percent fat (%)	18.5±3.4
Fat mass (kg)	12.1±3.7
Fat Free Mass (kg)	52.2±6.0
PAL	1.6±0.18
Basal VO_2 max (L/min)	0.31±0.04
Basal heart rate (bpm)	68.3±5.7

Data presented are mean±SD. BMI - Body mass index, PAL - physical activity level, bpm - beats per minute.

studies, ranged from 22.9 ml/kg/min to 47.8 ml/kg/min and ranged from fair to good for 60% of the subjects. There was moderate to good correlation between relative VO_2 max and select internal parameters such as maximal heart rate, respiratory rate, energy expenditure, tidal volume (the correlation coefficient ranging from 0.5 to 0.96) which reflects the internal validity of the measurements. The correlation of relative VO_2 max with subject characteristics showed that time to reach VO_2 max alone was significantly correlated (r=0.57, p=0.01/ r^2= 32.4%) with it. The time to achieve VO_2 max in turn was significantly correlated with PAL alone (r=0.48, p=0.03). When examined in a multivariate regression model adjusting for BMI, PAL continued to be associated with time to achieve VO_2 max. The time to achieve VO_2 max was consistently lower in all subjects as compared to time to exhaustion. The mean time to exhaustion was 1065±222 seconds and time to VO_2 max was 947±207 seconds and were significantly different using paired t test (p=0.007).

VO_2 max computed using the three prediction equations showed that equations 1, and 2 (12, 13) significantly overestimated VO_2 max. However, the bias computed from these two equations was not systematic when examined using the Bland Altman plot (Figure 2: Panel A, B). But there was a

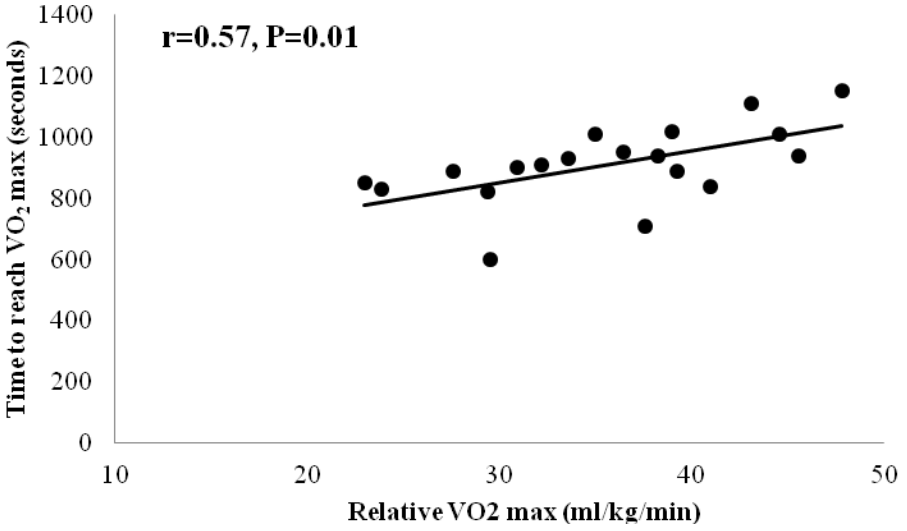
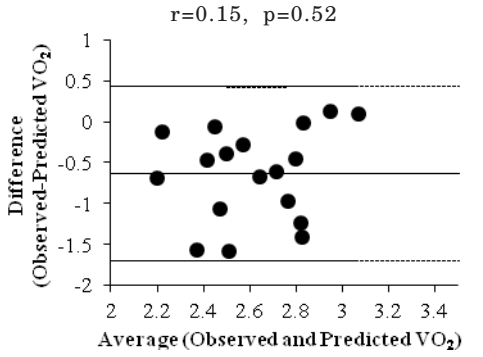


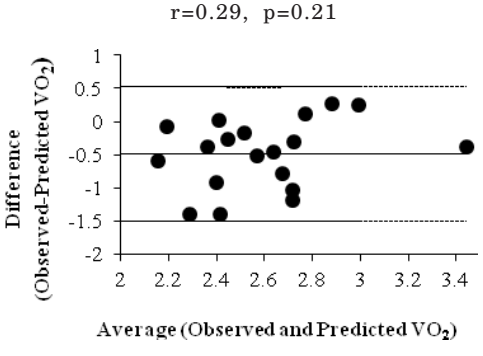
Fig. 1: Scatter plot representing the association between time to achieve VO_2 max and relative VO_2 max.



Panel A Equation 1 :

VO_2 Max= (0.046*Weight in Kgs)-0.012

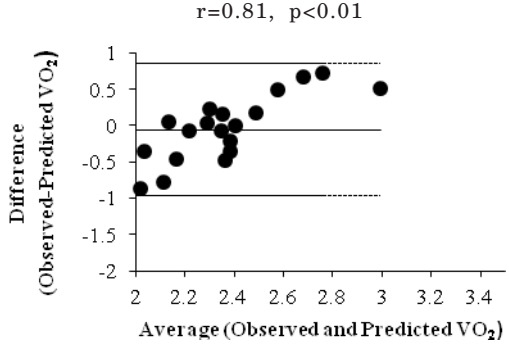
(12)



Panel B Equation 2 :

VO_2 Max= (0.04*Weight in kgs)+0.232

(13)



Panel C Equation 3:

VO_2 Max= (0. 018*Weight in kgs)+1.212

(14)

Fig. 2 : Bland Altman plot for comparison of the different prediction equations of VO_2 max with measured value for Indian population.

systematic error for equation 3 (Figure 2: Panel C), (14) such that the bias increased with increasing VO_2 max.

DISCUSSION

Data from the present study indicated that the time to achieve VO_2 max was a better predictor and correlated well with VO_2 max than the time to exhaustion. Physical activity level of an individual emerged to be a predictor of time to achieve VO_2 Max. Observed VO_2 max was lower than predicted VO_2 max values.

Conventionally time to exhaustion (TTE) is considered to be a marker of attainment of VO_2 max rather than time to achieve (TTA) VO_2 max [is the minimum time taken to reach VO2 max] or T lim VO_2 [which is the amount of the time a person maintains at VO_2 max at a minimum velocity (vVO_2 max)] (15). Difference between TTE and TTA is that former is based on subjective response and later is visualized by the investigator, adding greater advantage over TTE (16). It has also been shown that TTE among elite cyclists increased due to psychological factors without increase in fitness; further supporting the notion that time to exhaustion might not be a good index to predict physical fitness (17). T lim on the other hand is shown to be a marker of endurance and is said to correlate with the lactate threshold (18, 19). An inverse association has also been demonstrated between T lim VO_2 and VO_2 max (20). Though, determinants of T lim VO_2 are not yet known, it is said to have intraindividual variability as high as 21%. Making it an unfavorable measure in sports medicine (21). Of these three indices TTA VO_2 max is least explored and current study has attempted to evaluate its association with VO_2 max. In addition, factors, which could affect TTA VO_2 max, have also been explored.

In the present study, we found that TTA VO_2 max was closely related to the measured VO_2 max rather than TTE. Data also suggested that TTA VO_2 max entered the regression model with PAL emerging out as its predictor, than the actual measured VO_2 max. This was surprising, as we expected measured VO_2 max to enter the regression model. The fact that proportion of the variance between relative VO_2 max and time to achieve VO_2 max was 32% suggests that there might be other modulators which could be affecting either TTA VO_2 max or VO_2 max independently (22). However, this is beyond scope of the present analysis and could form the basis of future studies.

Measurement of maximal heart rate (MHR) to predict VO_2 max is not a new concept (23). For internal validity we did, measure 10 second averaged heart rate along with VO_2 max assessment. Data demonstrated a significant association between observed VO_2 max and MHR. Majority of the subjects achieved 75 to 80 % of their MHR at which point there was no change in the VO_2 despite an increase in the workload. Popularity of MHR to predict VO_2 max is for a simple reason that it is inexpensive and could be performed without any laboratory setup (24). Based on the present data it will be interesting to see whether time to MHR could also be used as an additional marker for attainment of VO_2 max. We could not evaluate this in the present study as continuous heart rate data was not available. Use of an averaged heart rate would not have given the accurate measure of TTA VO_2 max. Whether time to achieve MHR will emerge out be an indices of fitness along with MHR measurement remains to be tested.

VO_2 max derived from breath by breath analysis has been shown to be superior to VO_2 max derived through predicted equation (25). This is because prediction equations depend on multiple factors (26) and these factors vary depending on the population from which they are derived (27, 28). Data from the present study not only measured the VO_2 max but also compared the available

prediction equations for Indian population. VO_2 max computed using the three prediction equations showed that equations 1, and 2 (12, 13) significantly overestimated VO_2 max with systematic error noted in 3rd predicted equation.

In conclusion, this study estimated VO_2 max using standard protocol and compared it with factors affecting it in an Indian population. Physical activity emerged as strong predictor of time to achieve VO_2 max. An overestimation was noted in the VO_2 max values derived from the predicted equations. "There is a need for a future study which includes measurement of VO_2 max in a large Indian population with wide age range including both gender".

ACKNOWLEDGMENTS

This study was sponsored by the Indian Council of Medical Research (ICMR), New Delhi under the short term studentship scheme. We are thankful to Mr. Jeffery for helping in recruitment of subjects. Authors thank Mr. Vincent for helping with calorimetry data.

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