Validity of Queen’s College Step Test for estimation of maximum oxygen uptake in female students

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Background & objectives: Maximum oxygen uptake (VO$_2$ max) is internationally accepted parameter to evaluate the cardiorespiratory fitness. But determination of VO$_2$ max is restricted within well equipped laboratory because of its exhausting, hazardous and complicated experimental protocol. Various attempts have been made to enumerate indirect and easy protocols for prediction of VO$_2$ max but such record is unavailable in Indian women. The present study was conducted to validate the applicability of Queen’s College Step Test (QCT) for indirectly estimating the maximum oxygen uptake in female sedentary university students.

Methods: Forty sedentary female university students of same socio-economic background were recruited by simple random sampling from University of Calcutta, Kolkata. VO$_2$ max of each participant was determined by direct procedure and indirect QCT method with a gap of four days in between the tests. Direct estimation of VO$_2$ max comprised incremental bicycle exercise followed by expired gas analysis by Scholander micro-gas analyzer whereas VO$_2$ max was indirectly predicted by standard protocol of QCT.

Results: The difference between the mean VO$_2$ max values directly measured and indirectly predicted (PVO$_2$ max) was statistically significant ($P<0.001$). Limit of agreement analysis revealed poor confidence level for application of current method of QCT in the studied population. VO$_2$ max value exhibited significant correlation ($r = -0.83$, $P<0.001$) with QCT pulse rate. For precise and reliable estimation of VO$_2$ max in the studied population a new equation was computed.

Interpretation & conclusion: Our results suggest that QCT in its original form cannot be applied due to its poor agreement with the direct method but can be applied with the modified equation in this population to evaluate maximum oxygen uptake, especially when large numbers of participants are to be tested in absence of a well equipped laboratory.

Key words Indian females - QCT - sedentary - VO$_2$ max
Determination of cardiorespiratory fitness in terms of maximum oxygen uptake ($VO_2\max$) is restricted within the laboratory because of its exhausting and difficult experimental protocol\textsuperscript{1}. It is therefore desirable to find simple procedure for evaluation of $VO_2\max$ in large number of population, especially in the field and in absence of well equipped laboratory\textsuperscript{2}. Among various indirect protocols\textsuperscript{1, 3-8} Queen’s College Step Test or QCT is the simplest one\textsuperscript{8}, but its applicability has not yet been explored in Indian population, especially among women.

The present study was aimed to assess the suitability for application of QCT to predict $VO_2\max$ in sedentary female university students of West Bengal, India.

Material & Methods

Study population: Forty apparently healthy sedentary female university students of same socio-economic background having mean age, body height and body mass (BM) of 21.9±3.2 yr, 157.2±2.5 cm, and 49.6±5.0 kg, respectively, were selected for the study on the basis of random sampling from the post-graduate section of University of Calcutta, Kolkata, West Bengal, India. They were well explained about the experimental protocol to allay apprehension. They took light breakfast 2-3 h before the test and refrained from any energetic physical activity for that period. The participants had no history of any major disease and received no physical conditioning programme except some recreational sports.

The study was done during February to April, 2003, the whole experiment was performed at a room temperature varying from 27-29°C and at a relative humidity ranging between 70 and 85 per cent.

Experimental design: Maximum oxygen consumption of each subject was determined by both indirect and direct methods, respectively, at an interval of 4 days by random sequencing or cross-over design in which direct procedure was followed by indirect one in half the subjects whereas indirect one was followed by direct in other half of the subjects to avoid any possibility of bias. Subjects were asked to take complete rest at least for half an hour prior to the exercise, so that pulmonary ventilation and pulse rate might come down to a steady state\textsuperscript{9}.

Prediction of maximum oxygen uptake capacity ($PVO_2\max$) by QCT: The step test was performed on a stool of 16.25 inches (or 41.3 cm) height for a total duration of 3 min at the rate of 22 cycles/min which was set by a metronome. After completion of the exercise, the subject was asked to remain standing and the carotid pulse rate was measured from 5 to 20 seconds of the recovery period. This 15 second pulse rate was converted into beats/min and the following equation was used to predict the maximum oxygen uptake capacity\textsuperscript{8}.

$$PVO_2\max (\text{ml/kg/min}) = 65.81-(0.1847 \times \text{pulse rate in beats per min})$$

Direct measurement of maximum oxygen uptake capacity ($VO_2\max$): Muller’s magnetic brake bicycle ergometer (model of Max Plank Institute of Work Physiology, Germany) was used for the study. All the subjects first performed a sub-maximal exercise at 50 watt intensity for a duration of 5 min. Immediately after performing the sub-maximal exercise the intensity was increased to the first incremental intensity of 100 watt and thereafter the intensity was increased by 20 watt each 3 min till the subject stopped due to exhaustion. In the present study oxygen uptake was considered maximum when peak heart rate was greater than 180 beats/min and also by leveling off, \textit{i.e.,} when no further increase in oxygen uptake took place despite further increase in intensity, or the increase in oxygen uptake was less than 100 ml/min in response to the next higher intensity for repeated tests followed at an interval of 4 days\textsuperscript{9}. None of the subjects endured more than 8 min in this procedure of continuously increasing intensity of exercise.

Low resistance high velocity Collin’s Triple “J-type” plastic valve was used for the collection of gas by open circuit method\textsuperscript{9}. The valve was connected with the Douglas Bag (150 liter) and the expired gas was collected in the last minute of final intensity of exercise. Gas was also collected in the second minute of the exhausting (final) work load if signs of severe exhaustion supervened. No gas collection was made in the first minute of the work load. The expired gas
was measured in a wet gasometer (Toshniwal, Germany, CAT. No. CG 05.10) and the aliquots of gas samples were analyzed in a Scholander micro gas analysis apparatus (India) following the standard procedure\textsuperscript{10}. The peak heart rate was recorded manually from the time taken for 10 carotid pulsations immediately following the cessation of exhaustive exercise\textsuperscript{9}.

The study protocol was approved by the Ethics Committee of the University of Calcutta.

**Statistical analysis**: Paired t-test, Pearson’s product moment correlation, linear regression statistics and Bland and Altman approach for limit of agreement\textsuperscript{11} were adopted for statistical analysis of the data.

**Results & Discussion**

The mean value of $PVO_2\text{max}$ $35.5\pm4.4$ ml/kg BM/min (range 29.6-42.7) showed significant ($P<0.001$) difference with $VO_2\text{max}$ (32.8$\pm$3.8 ml/kg BM/min with a range of 24.2-40.1). Analysis of data by Bland and Altman\textsuperscript{11} method of approach for limit of agreement revealed that the limits of agreement between $PVO_2\text{max}$ and $VO_2\text{max}$ were large enough (0.4 to 6 ml/kg BM/min) with poor confidence intervals, indicating inapplicability of current protocol of QCT in this particular population. Moreover, significant ($P<0.001$) difference between $PVO_2\text{max}$ and $VO_2\text{max}$ indicated that it would not be justified to accept the prediction of maximum oxygen uptake as an equivalent to the direct value in the studied population by applying QCT as suggested by McArdle et al\textsuperscript{8}. However, recovery pulse rate of QCT exhibited significant negative correlation ($r=-0.83, P<0.001$) with directly measured $VO_2\text{max}$. On the basis of such highly significant correlation, a prediction equation $Y=54.12-0.13 X$ (SEE=0.344 ml/kg BM/min) was computed (Fig.) from the data obtained from the current study for more accurate and reliable assessment of $VO_2\text{max}$ in the young women of West Bengal. Prediction of $VO_2\text{max}$ from this new equation showed a variation of less than 5 per cent in 24 participants, 5-9 per cent in 10 participants, 10-14 per cent in 2 individuals and 15-19 per cent in 4 participants from their respective directly measured value of $VO_2\text{max}$. 

![Fig. Relationship between VO$_2$\text{max} and QCT pulse rate in young women of West Bengal, India. BM, body mass. Y=54.12-0.13X, SEE=0.344 ml/kg BM/min; r=-0.83, P<0.001.](image-url)
From the present observations it may be concluded that the newly derived or modified equation is recommended for application of QCT as a valid method to evaluate cardiorespiratory fitness in terms of VO\textsubscript{2}max for large numbers of sedentary female university students of West Bengal, India.

References


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