SHORT COMMUNICATION

VALIDITY OF 20 METER MULTI-STAGE SHUTTLE RUN TEST FOR ESTIMATION OF MAXIMUM OXYGEN UPTAKE IN FEMALE UNIVERSITY STUDENTS

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Abstract: Indirect protocols for determination of cardiorespiratory fitness in terms of VO\(_2\)\(_\text{max}\) have been developed to avoid the complicated experimental protocol of direct VO\(_2\)\(_\text{max}\) estimation especially in clinical setting. 20-meter multi stage shuttle run test (SRT) is one of such indirect protocols developed in Western population. Eighty eight (88) sedentary young healthy female university students (Age 22.8±1.79 years, Body height 159.0±4.28 cm and Body mass 52.47±4.17 kg) of same socio-economic background were recruited in the study by simple random sampling from University of Calcutta, Kolkata, India to validate the applicability of SRT in the studied population. They were randomly separated into “study group” (N=58) on which the existing experimental protocol of SRT was tested and “confirmatory group” (N=30) on which the modified equations were validated. VO\(_2\)\(_\text{max}\) of each participant was determined by direct procedure and indirect SRT method. The difference between the mean values of directly measured VO\(_2\)\(_\text{max}\) and indirectly predicted VO\(_2\)\(_\text{max}\) (PVO\(_2\)\(_\text{max}\)) in the “study group” was statistically significant (P<0.001). Limit of agreement analysis revealed poor confidence level for application of current method of SRT in the studied population. However, VO\(_2\)\(_\text{max}\) was significantly correlated with age (r = 0.71, P<0.001), body mass (r = 0.58, P<0.001), body height (r = 0.55, P<0.001), speed (r = 0.92, P<0.001) and PVO\(_2\)\(_\text{max}\) (r = 0.89, P<0.001). Modified norms in the form of simple and multiple regression equations were applied in the Confirmatory Group. Results suggested a good agreement of the modified equations of SRT in this population with substantially small SEE. Hence, the currently proposed modified norms are recommended to predict VO\(_2\)\(_\text{max}\) in the studied population.

Key words: Indian females shuttle run test sedentary VO\(_2\)\(_\text{max}\)
INTRODUCTION

Determination of cardiorespiratory fitness in terms of maximum oxygen uptake (VO$_2$max) is restricted within the laboratory because of its exhausting, labourious, complicated and expensive experimental protocol. In spite of immense clinical and physiological importance of the parameter, the direct estimation of VO$_2$max is often hazardous regardless of the type of ergometer used (1). It is therefore desirable to find simple procedure for evaluation of VO$_2$max especially in clinical settings where large number of subjects is to be evaluated either in the field or in absence of well-equipped laboratory (1–4). Among various indirect protocols (1–6) 20-meter multi-stage shuttle run test (SRT) is globally very popular one and has been widely used in different studies (7–11). Application of such indirect test needs proper validation in the particular population. Suminski et al. (12), Cooper et al. (13) and Chatterjee et al. (14) have studied the validity of SRT in different populations but authentic validity of the SRT with population specific simple and multiple regression norms in female University students of Kolkata, India is unavailable.

Therefore, the present study was aimed to

i) Assess the suitability for application of 20-m multi stage shuttle run test to predict VO$_2$max in sedentary female university students of Kolkata, India.

ii) Valid norms not only in the form of simple regression equation but also in the form of multiple regression equations in the studied population.

MATERIALS AND METHODS

Study population

Eighty eight (88) healthy sedentary female students of same socio-economic background having mean age, body height and body mass of 22.8±1.79 years, 159.0±4.28 cm and 52.47±4.17 kg, respectively were selected for the study by random sampling from the post-graduate section of the University of Calcutta, Kolkata, West Bengal, India. They were randomly separated into study group (N=58) on which the existing experimental protocol of SRT (5) was tested and confirmatory group (N=30) on which the modified equations were validated. The entire experimental protocol was well explained to all the participants to allay apprehension. They took light breakfast 2-3 hours 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 whole experiment was performed at a room temperature varying from 28-31°C and at a relative humidity ranging between 64 to 75%. Written informed consent was taken from all the subjects and human ethical committee of the Department of Physiology, University of Calcutta provided necessary approval to conduct the study.

Experimental design:

Maximum oxygen uptake (VO$_2$max) of each subject was determined by both indirect SRT method and direct method, 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 of the subjects whereas the indirect one was followed by the direct one in other half of the subjects to avoid any possibility of bias. Subjects were asked to take rest at least for half an hour prior to the exercise, so that pulmonary ventilation and pulse rate could come down to a steady state (15–17).

**Prediction of maximum oxygen uptake capacity (PVO\(_2\)\(_{\text{max}}\)) by SRT (5, 6):**

Subjects ran back and forth on a 20-meter course and must touched the line marked as “20 meter” at an initial speed of 8.5 km.hr\(^{-1}\). The speed of the shuttle runs got progressively increased at the rate of 0.5 km.hr\(^{-1}\) every minute, as dictated by the frequency of adjusted “beep” sound signal from a pre-recorded audio tape. Several shuttle runs made up each stage, and subjects were instructed to keep running pace with the sound signal for as long as possible. The last stage of the running pace was determined when subjects could no longer follow the pace. The last stage number announced by the pre-recorded audiotape was used to predict the PVO\(_2\)\(_{\text{max}}\) from the following equation:

\[
Y = 31.025 + 3.238 X - 3.248A + 0.1536AX
\]

[Where \(X\) = speed (km.h\(^{-1}\)) calculated corresponding to the stage: Speed = 8+0.5 stage No., \(A\) = age (year)]

**Direct measurement of maximum oxygen uptake capacity (\(\text{VO}_2\)\(_{\text{max}}\)):**

Muller’s magnetic brake bicycle ergometer (Model of Max Plank Institute of Ergology, Germany) was used for the study. All the subjects performed warm up exercise at a submaximal intensity of 50 watt for 5 minutes. Immediately after performing the warm up, the intensity was increased to the first incremental intensity of 100 watt and thereafter the intensity was increased by 20 watt every 3 min until the subject stopped due to exhaustion. In the present study, the oxygen uptake was considered maximum when peak heart rate was greater than 180 beats.min\(^{-1}\) and also by levelling off, 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\(^{-1}\) in response to the next higher intensity for repeated tests followed at an interval of 4 days (15, 17).

Low resistance high velocity Collin’s Triple “J Type” plastic valve was used for the collection of expired gas by open circuit method (15–17). The valve was connected with the Douglas Bag (150 L) and the expired gas was collected at the last minute of final intensity of exercise. Gas was also collected at the second minute of the exhausting (final) workload if signs of severe exhaustion supervened. No gas collection was made in the first minute of the workload. The volume of expired gas was measured in a wet gasometer (Toshniwal, Germany, CAT. No. CG05.10) and the aliquots of gas samples were analyzed in a Scholander micro-gas analysis apparatus following the standard procedure (18). The peak heart rate was recorded manually from the time taken for 10 carotid pulsations immediately following the cessation of exhaustive exercise (16, 17).

**Statistical analysis:**

Paired t-test, correlation and linear regression statistics and Bland and Altman
RESULTS AND DISCUSSION

Mean values of age, body height, body mass, body mass index (BMI), VO\textsubscript{2}\text{max} and PVO\textsubscript{2}\text{max} have been tabulated in Table I. Insignificant difference was depicted in all the parameters except the mean value of PVO\textsubscript{2}\text{max} that showed significant difference (P<0.001) with VO\textsubscript{2}\text{max} in the study group. Analysis of data by Bland and Altman (19) method of limit of agreement revealed that the limits of agreement between PVO\textsubscript{2}\text{max} and VO\textsubscript{2}\text{max} were large enough (0.135 to 10.12 ml.kg\textsuperscript{-1}.min\textsuperscript{-1}) with poor confidence intervals (Fig I), indicating inapplicability of the existing protocol of SRT (Leger et al. 1988) in this particular population. Moreover,

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1.png}
\caption{Plotting of difference between PVO\textsubscript{2}\text{max} and VO\textsubscript{2}\text{max} values against their means.}
\end{figure}

\begin{table}[h]
\centering
\caption{Physical and physiological parameters of the subjects.}
\begin{tabular}{|l|c|c|c|c|c|}
\hline
\textbf{Category} & \textbf{Age} (yrs) & \textbf{Body height} (cm) & \textbf{Body mass} (kg) & \textbf{VO\textsubscript{2}\text{max}} (ml.kg\textsuperscript{-1}.min\textsuperscript{-1}) & \textbf{PVO\textsubscript{2}\text{max}} (ml.kg\textsuperscript{-1}.min\textsuperscript{-1}) \\
\hline
Study Group (N=58) & 22.83±1.79 & 159.20±4.28 & 52.48±4.17 & 32.82±3.67 & 29.03±4.26* \\
Confirmatory Group (N=30) & 22.74±1.64 & 160.03±4.39 & 51.89±3.86 & 32.48±3.17 & 32.1±2.95 \\
\hline
\end{tabular}
\end{table}

Data are expressed as mean±SD. *P<0.001 when compared with VO\textsubscript{2}\text{max} in the same group.
significant (P<0.001) difference between 
PVO_{2max} and VO_{2max} indicated that it would 
not be justified to accept the prediction of 
maximum oxygen uptake in the studied 
population by applying the original existing 
protocol of SRT (5).

The present finding is contradictory to 
the observation of Chatterjee et al. (14). 
Their indirectly predicted VO_{2max} value 
(32.6±3.4 ml.kg^{-1}.min^{-1}) was significantly 
(P<0.001) higher than the present observation 
(29.03±4.26 ml.kg^{-1}.min^{-1}). They validated 
the SRT in female university students of 
West Bengal, India, and found insignificant 
difference between the directly measured and 
indirectly predicted values of VO_{2max}. Such 
contradiction with the present study might 
be due to the lower sample size (N=32) in 
the study of Chatterjee et al. (14) that 
recruited a pooled population from three different 
Universities of West Bengal, India. Their study delimited the subjects to all over 
the subcontinent of India, in respect of which a sample size of 32 was substantially small. Moreover, validity of such norm should be more population specific (rather than to a pooled population) as attempted in the present investigation. Earlier studies in the relevant field (14, 17, 20, and 21) also found significant difference between the directly measured and indirectly predicted 
values of VO_{2max} as also depicted in the 
current investigation. Chatterjee et al. (14) 
provided only a simple regression equation 
and no multiple regression norm was postulated.

VO_{2max} was significantly correlated with 
age (r = 0.71, P<0.001), body mass (r = 0.58, 
P<0.001), body height (r = 0.55, P<0.001), 
speed (r = 0.92, P<0.001) and PVO_{2max} (r = 
0.89, P<0.001) in the present study. On the 
basis of such significant correlations, prediction norms for VO_{2max} have been 
computed in the form of simple and multiple 
regression equations (Table II) for accurate 
and reliable assessment of VO_{2max} by using 
this 20-meter multi stage shuttle run test 
in the young females of Kolkata, India.

The values of correlation coefficients (r 
and R) are highly significant (P<0.001) in 
the present study. In multiple correlation 
statistics highest value of correlation 
coefficient was obtained when VO_{2max} was 
correlated with speed and height (R=0.94, 
R^2=0.88, P<0.001). The standard errors of 
estimate (SEE) of all the regression norms 
are substantially small (Table II). However, 
the regression norm that predicts VO_{2max} 
from height and speed, exhibited the lowest 
value of SEE among all the regression 

TABLE II: Simple and multiple regression norms for accurate assessment of maximum oxygen uptake from 20 meter multi stage shuttle run test in young females of Kolkata, India.

The simple regression norm is:

1. VO_{2max} (ml.kg^{-1}.min^{-1}) = 3.538 \times \text{Speed} - 4.9137 \quad [r=0.92, P<0.001, \text{SEE}=1.373 \text{ ml.kg^{-1}.min^{-1}}]

The multiple Regression norms are:

2. VO_{2max} (ml.kg^{-1}.min^{-1}) = 4.406 \times \text{Speed} - 0.5417 \times \text{Age} - 1.781 \quad [R=0.93, R^2=0.87, P<0.001, \text{SEE}=1.373 \text{ ml.kg^{-1}.min^{-1}}]
3. VO_{2max} (ml.kg^{-1}.min^{-1}) = 4.2827 \times \text{Speed} - 0.2213 \times \text{BM} - 1.222 \quad [R=0.93, R^2=0.87, P<0.001, \text{SEE}=1.373 \text{ ml.kg^{-1}.min^{-1}}]
4. VO_{2max} (ml.kg^{-1}.min^{-1}) = 4.261 \times \text{Speed} - 0.218 \times \text{BH} + 22.103 \quad [R=0.94, R^2=0.88, P<0.001, \text{SEE}=1.271 \text{ ml.kg^{-1}.min^{-1}}]

Application of the newly derived equations (Table I) in the confirmatory group revealed insignificant difference (P > 0.05) between PVO₂max (32.1 ± 2.95 ml.kg⁻¹.min⁻¹, 32.48 ± 3.17 ml.kg⁻¹.min⁻¹, 32.35 ± 2.77 ml.kg⁻¹.min⁻¹ and 32.46 ± 2.63 ml.kg⁻¹.min⁻¹ calculated from equations 1, 2, 3 and 4, respectively) and VO₂max (32.66 ± 3.33 ml.kg⁻¹.min⁻¹). Prediction of VO₂max from these equations showed a variation of less than 5% in 62 participants, 5–9% in 17 participants, 10–14% in 5 individuals and 15–19% in 4 participants from their respective directly measured value of VO₂max. Furthermore, the values of SEE of the currently proposed regression norms were also substantially small.

From the present investigation it may be concluded that the existing norm of SRT for prediction of VO₂max is not suitable for application in the studied population. However, the presently derived or modified regression norms would predict VO₂max more accurately and therefore these equations are recommended for application of 20 meter multi-stage shuttle run test as a valid method to evaluate the cardiorespiratory fitness in terms of VO₂max in sedentary female university students of Kolkata, West Bengal, India.

REFERENCES

14. Chatterjee P, Banerjee AK, Das P, Debnath P,


