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Validity of Cooper's 12-minute run test for estimation of maximum oxygen uptake in male university students

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ABSTRACT: The present study was conducted to validate the applicability of Cooper's 12-minute run test (CRT) for predicting VO_2max in male university students of Kolkata, India, to bypass the exhaustive and complicated protocol of direct estimation of VO_2max. Eighty-eight sedentary male university students recruited by simple random sampling from the University of Calcutta, Kolkata, were randomly assigned to the study group (N=58) and the confirmatory group (N=30). VO_2max of each participant was determined by the direct procedure and the indirect CRT method. The mean value of predicted VO_2max (PVO_2max) (42.8±4.0 $ml \cdot kg^{-1} \cdot min^{-1}$ with a range of 33.7–50.9) showed a significant difference with VO_2max (39.8±4.0 $ml \cdot kg^{-1} \cdot min^{-1}$ with a range of 33.5–47.7) in the study group. Limits of agreement between PVO_2max and VO_2max were large enough (0.10 to 5.94 $ml \cdot kg^{-1} \cdot min^{-1}$) with poor confidence intervals indicating inapplicability of the current protocol of CRT in the studied population. The prediction norm [$Y = 21.01X - 11.04$ (SEE = 0.193 $ml \cdot kg^{-1} \cdot min^{-1}$)] was computed from the significant correlation ($r = 0.93$, $P<0.001$) between distance covered in CRT and VO_2max. Application of this norm in the confirmatory group revealed an insignificant difference between PVO_2max and VO_2max. The modified equation is recommended for application of CRT as a valid method to evaluate the cardiorespiratory fitness in terms of VO_2max in sedentary male Indian youth.

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INTRODUCTION

VO_2max is defined as the highest attainable rate of aerobic metabolism during the performance of dynamic work that exhausts the subject within 5–10 min and it is internationally accepted as an index of one's cardiorespiratory fitness [1]. Besides physical parameters, other important determinants of VO_2max include environmental factors, working habit and health conditions. The method of direct estimation of cardiorespiratory fitness in terms of maximum oxygen uptake (VO_2max) is restricted to application within a well-equipped laboratory because of its laborious, complicated and difficult experimental protocol [1]. Thus, it is desirable to find a simple indirect procedure to evaluate VO_2max, especially in field studies [2,3]. Among various indirect protocols [1,4,5] the Queen's College step test has been evaluated as a valid method in the university students of India [2, 3]. But this test is not a true field test and essentially needs some equipment, e.g. a metronome, stool or 16.25-inch high stepping platform, unavailability of which often restricts the application of this test in the field. Another indirect test that requires less equipment would be a better option to predict VO_2max in the field.

Recently a couple of methods have been postulated in the Indian context to predict VO_2max from the percentage of body fat and non-exercise based VO_2max prediction equation in Indian college students [6,7]. The 20-metre multi-stage shuttle run test is a globally used indirect method for prediction of VO_2max that has been validated in female collegiate soccer players of Washington [8]. A 3-minute walking distance has been standardised with respect to gender, age and body composition in Japanese adults [9]. Development of a field test specifically for rowers has been suggested by Huntsman et al. [10] to restrict use of equipment. Marsh [11] tried to assess the validity of the American College of Sports Medicine's (ACSM's) submaximal treadmill running test in predicting VO_2max in moderately well-trained men of 18-34 years of age. It is clear from these recent reports that indirect protocols for VO_2max prediction should use inexpensive instruments as minimally as possible and the protocol must be validated in the specific population before its implementation. Among the different indirect field tests for prediction of VO_2max, Cooper's 12-minute run test (CRT) is a popular one and requires only a measuring tape to determine the distance covered in 12 min. But this test was enumerated and standardised in a Western population and application of this test in the Indian context has not yet been explored.

Therefore, the present study was aimed at assessing the suitability for application of a true field test, i.e., Cooper's 12-minute run test (CRT), to predict VO_2max in sedentary male university students of Kolkata, West Bengal, India.

Experimental approach

A longitudinal design was adopted in the present study to enumerate the applicability of the existing protocol (equation) of CRT in male university students of Kolkata, India. It was speculated that the existing protocol of CRT would not be applicable in the present population since it was originally developed in a Western population. Accordingly the subjects were divided into the study group and confirmatory group. The existing equation was tested on the study group and a new population-specific equation was computed using VO_2max as the dependent parameter and distance covered in CRT as the independent parameter. The applicability of the newly developed equation was validated in the confirmatory group by using Bland and Altman's method of limit of agreement analysis. Repeatability of the modified equation was also checked in both the groups.

Study population

Eighty-eight healthy sedentary male students of the same socio-economic background having mean age, body height and body mass of 22.8±1.7 years, 167.7±4.2 cm and 58.3±4.0 kg, respectively, were selected for the study by simple random sampling from the post-graduate section of the University of Calcutta, Kolkata, West Bengal, India. The sample size was calculated using PS-Power and Sample Size Calculation version 3.0.43 [12]. The power and the confidence interval were set at 80 and 95%, respectively. They were randomly separated into the study group (n=58) on which the existing experimental protocol of CRT was tested and confirmatory group (n=30) on which the modified equation was validated. The entire experimental protocol was well explained to all the participants to allay apprehension and written informed consent was obtained from them. They took a 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 undertook no physical conditioning programme except some recreational sports.

The whole experiment was performed during September 2012 to February 2013 at a room temperature varying from 26 to 29°C and at a relative humidity ranging between 72 and 83%. Human Ethical Clearance was obtained from the Human Ethics Committee, Department of Physiology, University of Calcutta.

Experimental design

Maximum oxygen uptake of each subject was determined by both indirect and direct methods, at an interval of 4 days, by cross-over design in which the direct procedure was followed by the indirect one in half the subjects whereas the indirect one was followed by the direct one in the 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 [2,3,13].

Prediction of maximum oxygen uptake capacity (PVO_2max) by CRT [14]

Subjects ran on a 400-metre round track for a total duration of 12 min. They were highly motivated to run as many laps as possible. The total number of laps was counted and the finishing point was marked. Total distance (in metres) covered in 12 min was calculated by multiplying the number of complete laps with 400 plus the distance covered (in metres) in the final incomplete lap. The distance in metres was converted into km and the following equation was used to predict the VO_2max [14] :

VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) = (22.351 x distance covered in kilometres) - 11.288

Direct measurement of maximum oxygen uptake capacity (VO_2max) [2]

Muller's magnetic brake bicycle ergometer (Model of Max Plank Institute of Ergology, Germany) was used for the study. All the subjects first performed a submaximal exercise at 75 W intensity for a duration of 5 minutes. Immediately after performing the submaximal exercise, the intensity was increased to the first incremental intensity of 155 W and thereafter the intensity was increased by 25 W 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$\cdot min^{-1}$ 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$\cdot min^{-1}$ in response to the next higher intensity for repeated tests followed at an interval of 4 days [2,3,13].

A low-resistance, high-velocity Collin's Triple "J Type" plastic valve was used for the collection of expired gas by the open circuit method [2,3,13]. 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) work load if signs of severe exhaustion supervened. No gas collection was made in the first minute of the work load. 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 analyser following the standard procedure [15]. The peak heart rate was recorded manually from the time taken for 10 carotid pulsations immediately following the cessation of exhaustive exercise [2,3,13].

Statistical analysis

The paired t-test was used to compute the significance of difference between mean values of VO_2max and PVO_2max. Pearson's product moment correlation was conducted to test the relationship between directly measured values of VO_2max and distance covered in CRT.

The linear regression statistic was applied to compute the linear regression equation for indirect prediction of VO_2max or PVO_2max (dependent variable) from the distance covered in CRT (independent variable). The Bland and Altman approach for limit of agreement analysis [16] was adopted to test the applicability of the new method.

RESULTS

A significant difference was found between VO_2max and PVO_2max in the study group (as shown in Figure 1). VO_2max showed a significant correlation with the distance covered in Cooper's test and accordingly the regression equation was computed for prediction of VO_2max (as shown in Figure 2). Necessary analyses were conducted to authenticate the applicability of this newly derived equation in the studied population (as shown in Figure 3 and Figure 4).

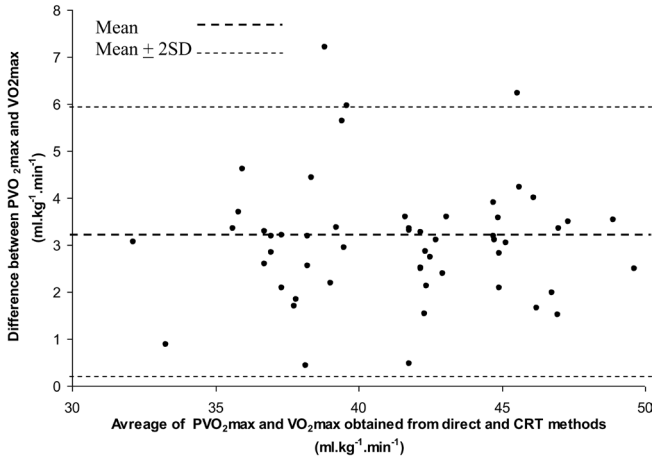

FIG. 1. Plot of difference between PVO_2max and VO_2max values against their directly measured values of VO_2max in the study group.

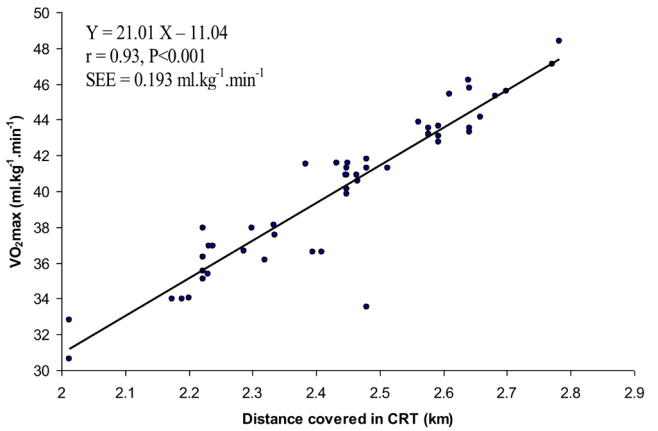

FIG. 2. Relationship between VO_2max and distance covered in CRT in the study group.

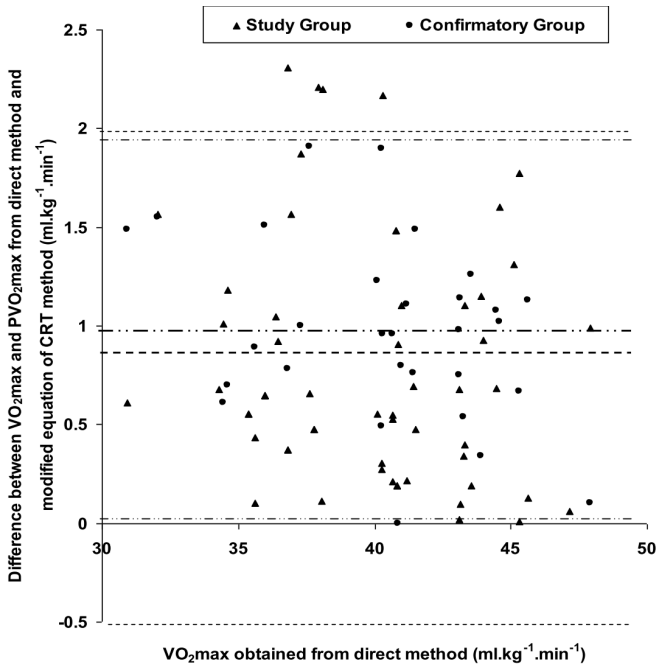

FIG. 3. Plot of difference between PVO_2max and VO_2max values against their directly measured values of VO_2max after application of the modified equation in the male study group and confirmatory group.

Mean (study group)
Mean ± 2SD (study group)
Mean (confirmatory group)
Mean ± 2SD (confirmatory group)

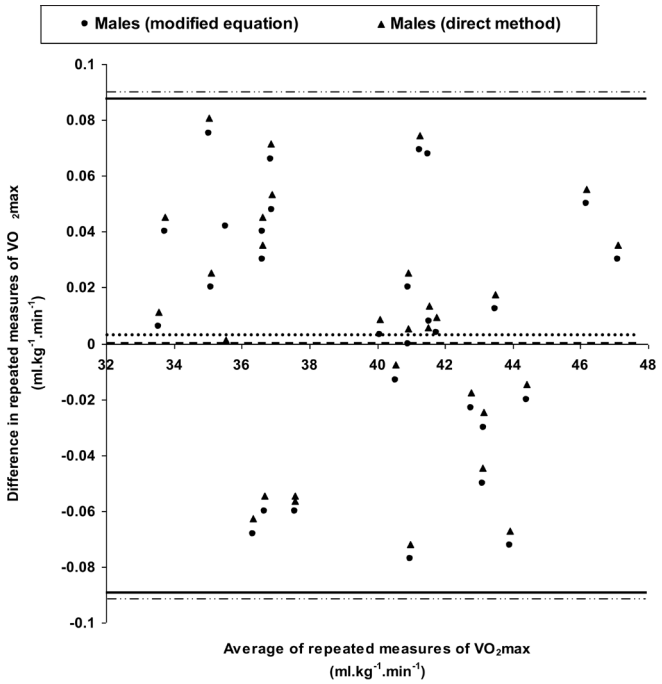

FIG. 4. Repeated measures of VO_2max by using the modified equation.

Mean (indirect method)
Mean ± 2SD (indirect method)
Mean (direct method)
Mean ± 2SD (direct method)

DISCUSSION

The VO_2max value obtained in the present study corroborated the earlier report from this laboratory in the same population [2]. That study was also conducted to enumerate the applicability of another indirect protocol of VO_2max prediction, i.e., the Queen's College Step Test. In the context of the available literature the present study is very significant since it modifies an indirect protocol that predicts cardiorespiratory fitness from distance covered in 12 min in young Indian males. Oxygen uptake is one of the reliable predictors of metabolic indices [17]. A study in Korean workers indicated that the use of a non-exercise regression model can predict the work-related physical activity in terms of cardiorespiratory fitness [18]. It was also hypothesized that the particular form of work load not only represents the physical work load quite accurately but also contributes to increases in VO_2max [19]. Oxygen uptake is also influenced by life style, addiction, dietary practice and exercise habit [20,21,22,23].

The PVO_2max value (42.8±4.0 $ml \cdot kg^{-1} \cdot min^{-1}$ with a range of 33.7–50.9) showed a significant difference with VO_2max (39.8± 4.0 $ml \cdot kg^{-1} \cdot min^{-1}$ with a range of 33.5–47.7) in the study group. Analysis of data by the Bland and Altman [16] method of limit of agreement revealed that the limits of agreement between PVO_2max and VO_2max were large enough (0.10 to 5.94 $ml \cdot kg^{-1} \cdot min^{-1}$) with poor confidence intervals (as shown in Figure 1), indicating inapplicability of the current protocol of CRT in this particular population. Moreover, a 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 CRT as suggested by Cooper [16]. However, the distance covered in CRT showed a significant correlation ($r = 0.93$, $P<0.001$) with directly measured VO_2max. On the basis of such a highly significant correlation, the prediction equation $Y = 21.01X - 11.04$ (SEE = 0.193 $ml \cdot kg^{-1} \cdot min^{-1}$) was computed (Figure 2) from the data obtained in the current study for more accurate and reliable assessment of VO_2max in the young males of Kolkata, West Bengal, India. The standard errors of regression coefficient and constant were 2.736 and 1.505, respectively.

Application of the newly derived equation in the confirmatory group revealed an insignificant difference between PVO_2max (39.7± 3.7 $ml \cdot kg^{-1} \cdot min^{-1}$) and VO_2max (39.3±4.5 $ml \cdot kg^{-1} \cdot min^{-1}$). Moreover, the standard error of estimate of the regression norm was substantially small (SEE = 0.193 $ml \cdot kg^{-1} \cdot min^{-1}$). Prediction of VO_2max from this new equation showed variation of less than 5% in 62 participants, 5–9% in 14 participants, 10–14% in 8 participants and 15–19% in 4 participants from their respective directly measured value of VO_2max. Application of Bland and Altman's analysis between directly measured VO_2max and indirectly predicted VO_2max from the newly derived equation revealed substantially small limits of agreement (-0.31 to 2.09 $ml \cdot kg^{-1} \cdot min^{-1}$) in the studied population (as shown in Figure 3).

Repeatability of the modified equation in the studied population was tested in the same population according to the guidelines of Bland and Altman [10]. It was observed that the mean difference between repeated measures of VO_2max (determined by both the direct method and the indirect modified method) was insignificantly different from zero (Figure 4). According to the definition of "repeatability coefficient" [24], it is expected that 95% of differences would be less than two standard deviations (±2SDs), which has been met in the present investigation. The standard deviations between repeated measures of each method separately were computed and the standard deviations of differences between the means for each method were also computed to determine the repeatability coefficients for the direct method and indirectly modified method [15]. The mean differences of repeated measures were 0.0032 $ml \cdot kg^{-1} \cdot min^{-1}$ and 0.0048 $ml \cdot kg^{-1} \cdot min^{-1}$ for the modified equation and the direct method, respectively. The corresponding values of repeatability coefficients were ±0.0465 $ml \cdot kg^{-1} \cdot min^{-1}$ and ±0.0363 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively.

CONCLUSIONS

From the present observation it may be concluded that the presently derived or modified equations would predict VO_2max in the studied population more accurately than the existing original equation. Therefore the newly derived norm is recommended for application of Cooper's 12-minute run test as a valid method for correct, accurate and precise evaluation of cardiorespiratory fitness in terms of VO_2max in male sedentary university students of Kolkata, West Bengal, India.

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