Original Article

A Prediction Equation to Estimate the Maximum Oxygen Uptake of School-Age Girls from Kolkata, India

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Abstract

Background: **The 20-metre multistage shuttle run test is a useful method for the regular monitoring of aerobic fitness. However, the validity of the test should be established in the particular population prior to application. The aim of the study was to validate the applicability of the 20-metre multistage shuttle run test in non-athlete, girls from Kolkata, India.**

Methods: **Thirty-six untrained girls from different schools in Kolkata (age range 14–16 years) were recruited for the study. Direct estimation of cardiorespiratory endurance (VO_2max) comprised treadmill exercise followed by expired gas analysis using Scholander micro-gas analyser. VO_2max was indirectly predicted by the 20-metre multistage shuttle run test.**

Results: **The difference between the mean (SD) VO_2max values of the direct measurement, 32.91 (2.66) ml.kg^{-1}.min^{-1}, and the 20-metre multistage shuttle run test, 33.79 (2.56) ml.kg^{-1}.min^{-1}, was statistically significant ($P < 0.01$). However, limits of agreement analysis suggested that the 20-metre multistage shuttle run test can be applied for use with the studied population. Intra-class correlation coefficients also suggested good reliability of the 20-metre multistage shuttle run data.**

Conclusion: **The results suggest that the use of the 20-metre multistage shuttle run test for the prediction of VO_2max is justified in the studied population. For better prediction of VO_2max, a new equation has been developed based on the present data for untrained girls from Kolkata.**

Keywords: *anaerobic threshold, chest and respiratory, exercise test, female adolescents, oxygen consumption, physical fitness, sedentary lifestyle*

Introduction

Direct measurement of maximum oxygen uptake (VO_2max) is recognised as the best single index of aerobic fitness (1). However, the direct measurement of VO_2max is difficult, exhausting, and often hazardous to perform regardless of the type of ergometer used (2). Because the direct testing procedure is rather complicated for larger populations, several indirect running and walking tests have been dev eloped. Scientists often calculate VO_2max using indirect protocols (3). It has been reported that equations for predicting VO_2max indirectly using running and walking tests are very sensitive to the studied population. Therefore, before applying any indirect protocol for prediction of VO_2max, the validity of the test should be established in a particular population. The 20-m multistage shuttle run (20-m MST) (4,5) is often used to measure aerobic capacity (6–10). Cooper et al. (11) studied the repeatability and criterion-related validity of the 20-m MST as a predictor of maximum oxygen uptake in active young men. Suminski et al. (12) established the validity of the 20-m MST for measuring the aerobic fitness of Hispanic youth 10 to 12 years of age. Chatterjee et al. (13,14) studied the validity of 20-m MST in junior taekwondo players and female university students in India.

Recent studies have suggested that sex-specific equations allow more accurate prediction of VO_2max using 20-m MST data (15). For this reason, a combined male and female population was not used in this study; only girls were recruited as subject. The present study was undertaken to assess the applicability of the 20-m MST for the prediction of VO_2max in untrained school-

age girls from Kolkata, India, and to develop a regression equation for use with this particular population.

Subjects and Methods

Subjects

Thirty-six untrained girls from 3 different schools (12 girls from each) in Kolkata were selected for the study. The girls were in Standard 8 (n = 18) and Standard 9 (n = 18). The experimental protocol was fully explained to the participants. They had a light breakfast 2–3 hours before the test and refrained from any energetic physical activity for 4 hours before the test. The participants had no history of any major disease and did not follow any physical-conditioning program, except for occasional recreational sports. These recreational sports included table tennis, badminton, and volleyball. They played these games, on average, twice per week for half an hour to one hour. Considering their lifestyle and habitual activity level, these girls were considered representative of the majority of school-age girls from Kolkata. The tests were demonstrated to the subjects before actual administration. All participants signed a statement of informed consent. All institutional policies concerning human research subjects were followed. Ethical approval was granted by Research Ethics Committee of the institution.

Experimental design

The maximum oxygen consumption of each subject was determined by both indirect and direct methods with an interval of 4 days. The indirect method was completed first by half of the subjects, followed by the direct method; the other half of the subjects completed the direct method first to avoid any possibility of bias. Subjects were asked to take complete rest for at least half an hour prior to the tests so that pulmonary ventilation and the pulse rate would be at steady state before the test (16).

Indirect measurement of VO_2max using the 20-m MST

Subjects ran back and forth on the 20-metre course and touched the 20 metre (m) line after running at an initial speed of 8.5 km.hr^{-1}. The speed of the shuttle runs became progressively faster (0.5 km.hr^{-1} every minute), in accordance with a pace dictated by a sound signal on an audio tape. Several shuttle runs made up each stage, and subjects were instructed to keep pace with the signal for as long as possible. When the subjects could no longer maintain the pace, the last stage completed was used to predict VO_2max using the equation of Leger and Gadoury, 1989 (5):

$$Y = 31.025 + 3.238\,X - 3.248\,A + 0.1536\,AX$$

where

$Y = VO_2$max (ml.kg^{-1}.min^{-1})

X = maximum shuttle run speed (km.hr^{-1})

A = age (year)

Direct measurement of VO_2max

The subjects walked on a treadmill to warm up at a speed of 4 km/hr at 4.5° inclination for 5 minutes (17). The warm-up period was followed by running at a constant speed of 7 km.hr^{-1} for a maximum duration of 5 minutes. The inclination was increased successively from 4.5° until the subject was unable to continue the task; in no case did the incline exceed 7.5°. The criteria for maximality was exhaustion and withdrawal from running within the scheduled 5-minute period, when the heart rate was approximately their predicted maximum heart rate and when a further increase in the incline did not result in any significant rise in oxygen uptake (16).

Gas analysis

A low-resistance high-velocity Collin's Triple "J type" plastic valve was used for the collection of gas using the open circuit method (16). The valve was connected to a Douglas Bag (150-L), and the expired gas was collected during the 2nd minute of the final running period, if signs of severe exhaustion were observed. No gas collection was made during the 1st minute of the run. The expired gas was measured using a wet gasometer (Toshniwal, Germany, CAT No. C G 05.10), and aliquots of the gas samples were analysed using a Scholander micro gas analysis apparatus following the standard procedure (18).

Validity of the results

The repeatability was investigated by having 21 of the subject perform the test twice. Intra-class correlation coefficients (ICC) were used to determine the test–retest reliability. The ICC was 0.81.

Statistical analysis

Paired t tests, intra-class correlation coefficients, Pearson's product moment correlations, linear regression statistics, and the Bland and Altman (19) approach for limits of agreement were adopted for statistical analysis of the data. Statistical Package for Social Sciences (SPSS) Microsoft Windows Release version 16.0 (SPSS Inc., Chicago, IL) was used for statistical analysis.

Results

The means and standard deviations of the physical characteristics, the shuttle run-predicted VO_2max values ($SPVO_2$max), and the directly measured VO_2max values of the participants are presented in Table 1. Significant variation was observed ($P < 0.01$) between the directly measured and predicted VO_2max values. The mean difference between VO_2max and $SPVO_2$max was -0.87 $ml.kg^{-1}.min^{-1}$ with a 95% confidence interval -0.59 to -1.17 $ml.kg^{-1}.min^{-1}$, indicating that the 20-m MST predicts a maximum oxygen uptake capacity between -0.59 and -1.17 $ml.kg^{-1}.min^{-1}$. The intra-class correlation coefficients (ICC) for the VO_2max values obtained from direct measurement and from the 20-m multistage shuttle run test was 0.96 by using the equation of Leger and Gadoury (5).

Analysis of the data using the Bland and Altman (Bland and Altman, 1986) method for limits of agreement between $SPVO_2$max calculated using the equation of Leger and Gadoury and VO_2max measured by the direct method revealed that the limits of agreement were -0.83 to -2.57. These limits are small enough that the 20-m MST can be used confidently in place of the direct method (Figure 1). The limits of agreement analysis suggests that application of the present form of the 20-m MST may be justified for the studied population. A highly significant correlation ($r = 0.87$, $P < 0.01$) existed between the maximum speed of the 20-m MST and VO_2max.

The following equation, derived using the present data, can be used to predict the aerobic fitness of untrained school-age girls from Kolkata.

$Y = 10.461 + 5.700\ X - 2.027\ A + 0.001\ AX$

where

Y = VO_2max ($ml.kg^{-1}.min^{-1}$)

X = maximum shuttle run speed ($km.hr^{-1}$)

Discussion

Better limits of agreement existed between the two methods when the newly developed equation was used to predict VO_2max from the 20-m MST data. The limits of agreement when using the new equation were 1.54 and -1.81. When using this newly derived equation, the shuttle run-predicted VO_2max values for 94% of the participants fell within the limits of agreement. On the other hand, when the equation of Leger and Gadoury was used to predict VO_2max from the 20-m MST data, the shuttle run-predicted VO_2max values for 89% of the participants fell within the limit of agreement. In the present study, the ICC was also assessed because Pearson's correlation measures the strength of a relationship between two measurements, not the agreement between them (19). The ICC found between the directly measured VO_2max and the shuttle run-predicted VO_2max using the new equation was 0.97. As a general guideline, ICC values above 0.75 indicate good reliability, and those below 0.75 indicate poor to moderate reliability (20). The ICC value suggests that the reliability of the 20-m multistage shuttle run test using the newly derived equation instead of direct measurement is sufficient for the studied population. The ICC value also suggests an equally good reliability of the 20-m MST when using the equation of Leger and Gadoury (5). However, as the limits of agreement analysis indicated a better agreement when using the newly derived equation, we recommend the use of the new equation for the prediction of VO_2max from 20-m MST data in the studied population.

Table 1: Physical parameters and predicted and measured VO_2max values for the test subjects ($n = 36$)

Parameter	Minimum	Maximum	Mean	SD
Age (years)	14.00	16.00	15.30	0.86
Height (cm)	146.21	154.80	150.88	2.16
Weight (kg)	36.00	49.60	40.91	2.73
VO_2max ($ml.kg^{-1}.min^{-1}$)	29.00	37.86	32.91	2.66
$SPVO_2$max ($ml.kg^{-1}.min^{-1}$)	29.42	38.66	33.79	2.56
Shuttle run speed ($km.hr^{-1}$)	8.50	10.50	9.34	0.66

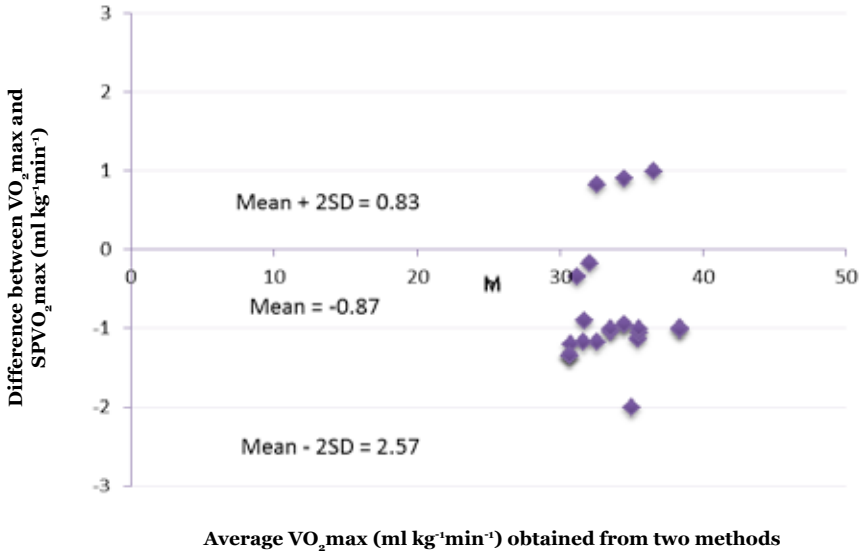

Figure 1: Difference between the VO_2max values obtained from direct measurement and those obtained from the 20-metre MST data (using the equation of Leger and Gadoury; 5) plotted against their means (Bland and Altman method of approach; 19)

Conclusion

From the present observations, we concluded that the 20-metre multistage shuttle run test is a valid method to evaluate aerobic fitness in terms of VO_2max for school-age girls (age 14–16 years) from Kolkata, India. We recommend using the equation developed based on the present data. The 20-metre multistage shuttle run test is a useful method for the regular monitoring of aerobic fitness in the studied population when a large number of subjects must be evaluated without the help of a well-equipped laboratory and with a lower cost and within a short period of time.

Authors' Contributions

Conception and design: PC, AKB
Obtaining of funding, administrative, technical, or logistic support: AKB
Collection, assembly, analysis, and interpretation of the data; drafting and critical revision of the article: PC, PD
Provision of study materials or patients, statistical expertise, final approval of the article: PC, AKB, PD

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