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Applicablity of an Indirect Method to Predict Maximum Oxygen Uptake in Young Badminton Players of Nepal

Pinaki Chatterjee[1, +], Alok K. Banerjee [2], Paulomi Das [3]

[1] Department of Physiology, S. R. College of Dental Sciences and Research, Faridabad, India
[2]University of Kalyani, West Bengal, India
[3]Nepalgunj Medical College, Chisapani, Nepal

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Abstract. The aim of the study was to validate the applicability of the 20-m Multi Stage Shuttle Run Test (20-m MST) in young badminton players of Banke district, Nepal. For application of direct method "cross-over design" (random sequencing) was followed. For validity of the results, repeatability was investigated where 24 subjects performed the test (20-m MST) twice. Intra-class correlation coefficients (ICC) were used to determine test-retest reliability. Forty young badminton players (age range 12 ~ 17 years, sex- male) from different sports academies of Banke district, Nepal were recruited for the study. Direct estimation of Maximal oxygen consumption (VO_2 max) comprised of treadmill exercise followed by expired gas analysis by scholander micro-gas analyzer, whereas VO_2 max was indirectly predicted by 20-m MST. The difference between the mean (± standard deviation) VO_2 max values of direct measurement (VO_2 max = 46.85 ± 3.90 ml/kg/min) and the 20-m MST [Shuttle predicted VO_2 max ($SPVO_2$ max) = 46.08 ± 3.88 ml/kg/min] was statistically significant. The results suggest that the application of the present form of 20-m MST may not be justified in the studied population. For better prediction of VO_2 max a new equation has been developed based on present data. The new equation is recommended to be used for the studied population.

Key Words: cardiorespiratory fitness, aerobic Capacity, beep test, badminton.

1. Introduction

Direct measurement of maximum oxygen uptake (VO_2max) is recognized as the best single index of aerobic fitness (Astrand and Rodahl, 1986). The test of direct measurement of VO_2 max is difficult, exhausting and often hazardous to perform regardless the type of ergometer used (Fox, 1973). This is why scientists often perform this test in indirect protocols to predict VO_2 max (Das et al., 1995). But before applying any indirect protocol for the prediction of VO_2 max, the validity of the test should be established in particular population. The 20-m MST (Leger and Gadoury, 1989; Leger et al., 1988) popularly known as Beep test, is often used world wide for measurement of aerobic capacity (Guerra et al., 2002; Mota et al., 2002; Vicente-Rodriguez et al., 2003; Vicente-Rodriguez et al., 2004; Wong et al., 2001). Cooper et al., 2005 studied the repeatability and criterion related validity of the 20-m multistage fitness test as a predictor of maximal oxygen uptake in active young men. Suminski et al., 2004 established the validity of the 20-m MST for measuring aerobic fitness of Hispanic youth of 10 to 12 years of age. Effort has been made to validate its applicability in junior Taekwondo players of India, Nepalese adult females and males by Chatterjee et al., 2006, 2010, 2010a. However, studies on the validity and suitability of this test in the sports population of Nepal are scanty (Chatterjee et al., 2009) until now. Previous study has indicated that there are sport-specific differences when predicting VO_2 max from the multistage shuttle run test (Gibson et al., 1998). In another study by Cetin et al., 2005 on Taekwondo athletes, the authors conclude that Maximal oxygen consumption (VO_2 max) can be predicted from shuttle run test scores, but not as indicated with the test package. In order to obtain the true score one must apply a regression equation (Cetin et al., 2005).

Badminton is becoming one of the popular sports in Nepal and a huge number of youngsters undergo Badminton training in different sports academies of Nepal. It is therefore desirable to find a simpler procedure like 20-m MST for such a population to regularly monitor their aerobic fitness. Keeping in view, all these aspects, the present study was carried out with an aim to assess the applicability of 20-m MST to

[+] Corresponding author. *Email address*: drpinakichattopadhyay@gmail.com pnkchatterjee@yahoo.com

predict maximum oxygen uptake in young male Badminton players of Banke district, Nepal.

2. Methods

2.1. Subjects

40 young male badminton players (age range 12 ~ 17 years old) from different sports academies of Banke district were volunteered for the study. The subjects had the mean age of 13.83 yr, body height of 162.35 cm, and weight of 52.11 kg. They all have a training background of 2-3 yr. 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 that period. The tests were demonstrated to the subjects before actual administration and the subjects that agreed signed a statement of informed consent. The subjects were refrained from vigorous exercise during a day before the test.

All institutional policies concerning the human subjects in research were followed. Ethical approval from competent institutional authority was taken.

2.2. Experimental Design

Maximum oxygen consumption of each subject was determined by both indirect (20-m MST) and direct methods at an interval of 4 days by random sequencing in a counter balance order. Indirect one in the half of the subjects followed the direct method whereas indirect one was followed by the direct method 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 steady state (Chatterjee et al., 1986) .

2.3. Prediction of Maximum Oxygen Uptake Capacity by the 20-M MST (Indirect Method)

Subjects started running back and forth a 20-meter (m) course and must touch the 20-m line. The initial speed was 8.5 km/h, which got progressively faster (0.5 km/h every minute), in accordance with a pace dictated by a sound signal on an audiotape. Several shuttle runs made up each stage, and subjects were instructed to keep pace with the signal for as long as possible. When the subject could no longer follow the pace, the last stage announced was used to predict maximal oxygen uptake using the equation of Leger et al (Leger et al., 1988) which is $Y = 31.025 + 3.238 X - 3.248A + 0.1536AX$, Where,

Y= VO_2max (ml/kg/min)

X= Maximal shuttle run speed (km/h)

A= Age (yr)

2.4. Direct Measurement of Maximum Oxygen Uptake Capacity (Direct Method)

The subjects walked on a treadmill to warm up at a speed of 4 km/hr at a 4.5 inclination for duration of 5-minute (Slonim et al., 1957). Running at a constant speed of 7 km/h for a maximum duration of 5 minute (min) followed this. The inclination gradient was increased successively (0.5/min) from 4.5 until the subject was unable to continue the task. In no case did it exceed 7.5 inclinations. The criteria for maximality was exhaustion and withdrawal from running within the scheduled 5 min period, when the heart rate reached their predicted maximum heart rate and when a further increase of inclination did not bring about any significant rise in oxygen uptake for repeated tests followed at an interval of 4 days (Chatterjee et al., 1986).

Heart rate was measured continuously at 5-sec. intervals during the whole duration of treadmill exercise using Sport Tester PE-3000 system (Polar Electro, Finland).

2.5. Gas Analysis

Low resistance high velocity Collin's Triple "J type" plastic valve was used for the collection of gas by open circuit method (Chatterjee et al., 1986). The valve was connected with the Douglas bag (150-liter) and the expired gas was collected in 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 expired gas measured in a wet gasometer (Toshniwal, Germany CAT No. C G 05.10) and the aliquots of gas samples were analyzed in a Scholander micro gas analysis apparatus (India) following the standard procedure (Consolazio et al., 1963).

2.6. Validity of the Results

Repeatability was investigated where 24 subjects performed the test twice. Intra-class correlation

coefficients (ICC) were used to determine test-retest reliability. The ICC found was 0.81.

2.7. Statistical Analysis

Paired t-test, Intra-class correlation coefficients, Pearson's product moment correlation, linear regression statistics and Bland and Altman approach for limit of agreement were adopted for statistical analysis of the data. Statistical Package for Social Sciences (SPSS) MS windows Release 16.0 was used for statistical analysis.

3. Results

Means and standard deviations of physical characteristics, predicted VO_2 max ($SPVO_2$ max) by 20-m MST and directly measured VO_2max of the badminton players are presented in the table 1.

Table 1. Physical Parameters, Predicted and Measured VO2 max of the Badminton Players (*N = 40*)

Parameters	Minimum	Maximum	Mean	Standard Deviation(SD)
Age (yr.)	12	17	13.8	1.2
Height (cm)	146.00	178.00	162.35	7.94
Weight (kg)	35.00	80.00	52.11	9.24
VO_2max ‡ (ml/kg/min)	39.55	55.55	46.85	3.90
$SPVO_2$max * (ml/kg/min)	39.44	54.35	46.08	3.88
Speed(km/h)	10.0	13.0	11.17	0.75

‡VO_2 max: maximum oxygen uptake / * $SPVO_2$ max: predicted VO_2 max

The mean value (± SD) of the VO2 max determined by direct method and the predicted VO2 max (SPVO2 max) by 20-m MST show significant variation ($p<0.10$). The mean difference between VO2 max and predicted VO2 max (SPVO2max) was 0.76 ml/kg/min with 95% confidence interval 0.38 to 1.14 ml/kg/min indicating that 20-m MST predict the maximum oxygen uptake capacity within a range of 0.38 to 1.14 ml/kg/min.

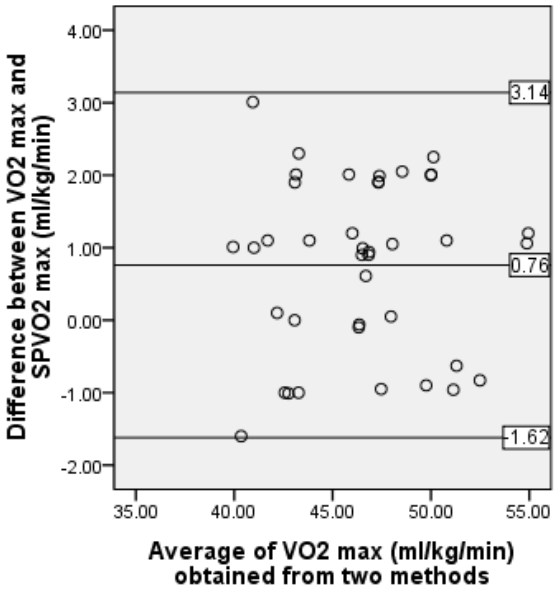

Figure 1: Plotting of difference between VO_2max values obtained from direct measurement and 20-meter MST (using the equation of Leger et al., 1988) against their means (Bland and Altman method of approach).

We also calculated intra-class correlation coefficients (ICC) for the VO2max values obtained from direct measurement and 20-m multistage shuttle run test using the equation of Leger et al., 1988. The ICC found was 0.95.

Analysis of data by Bland and Altman method (Bland and Altman, 1986) of approach for limits of agreement between VO2 max and predicted VO2 max (SPVO2max) reveals that limits of agreement are 3.14 and -1.62 (Fig. 1). These are large enough parameter for 20-m MST to be used confidently in place of direct procedure. Limits of agreement analysis suggest that application of the present form of 20-m MST may not be justified for the studied population.

However, in this present study, highly significant correlation ($r = 0.85$, $p < 0.01$) existed between the maximal speed of 20-m MST and VO2max. The following equation, derived on the basis of present data will better predict the aerobic fitness in young Badminton players of Banke district, Nepal.

Y= 9.651 + 5.178X–1.495A +. 001AX,

Where

Y= VO_2max (ml/kg/min),

X= Maximal shuttle run speed (km/h)

A= Age (yr)

Using the above new equation for estimation of VO_2max for the present data, no significant difference is observed ($p>0.10$) between the values of VO_2max measured and predicted by direct and 20 m-MST respectively. Using this equation limits of agreements (2.34 and -2.14) are small enough parameter for 20-m MST to be used confidently in place of direct measurement.

4. Discussion

Better limits of agreement exist between the two methods when this newly developed equation is used for prediction of VO_2max from 20-m MST. The limits of agreement in this case are 2.34 and -2.34. **.** In the present study, ICC was additionally assessed because Pearson's correlation measures the strength of a relationship between two measurements, not the agreement between them (Bland and Altman, 1986). The ICC found between the directly measured VO_2max and shuttle predicted VO_2max using this new equation was 0.98. As a general guideline, ICC values above 0.75 indicate good reliability and those below 0.75 indicate poor to moderate reliability (Portney and Watkins, 1993). The ICC value suggests that the reliability of 20-m Multistage shuttle run test using the newly equation in place of direct measurement is good enough for the studied population. The ICC value also suggests equally good reliability of 20-m MST while using the equation of Leger et al. 1988. However, as limits of agreement analysis indicates better agreement while using the newly derived equation, this equation is recommended to be used for prediction of VO_2max from 20-m MST in the studied population.

A recent study has indicated that there are sport-specific differences when predicting VO_2 max results yielded from the 20 meter MST (Cetin et al., 2005). In a previous study on Taekwondo players, it was concluded that VO_2max could be predicted from shuttle run test scores, but to obtain the true score a regression equation must be applied [17]. Recent studies by Chatterjee et al. on two different population of Nepal also suggested separate regression equations for prediction of VO_2 max in a particular population (Chatterjee et al., 2010; Chatterjee et al., 2010a). In our present study too, it is found that the application of 20-m MST in its present form may not be justified in the studied population, but for better prediction a new regression equation has been derived.

5. Conclusions

The newly derived regression equation based on the present data is recommended as a valid method to evaluate aerobic fitness in terms of VO_2max within young Badminton players of Banke district, Nepal.

Key Messages

* The limitation of this study is that the subjects are limited to specific age group of 12 to 17 years and practicing the sport of badminton only. Efforts should be taken to validate the applicability of 20-m MST in various sports disciplines of Nepal.

* The equation developed on the basis of present data is recommended to be used for the assessment of cardio-respiratory fitness in boys (12~17 years age) practicing badminton regularly.

* This is likely to be the most useful method when a large number of subjects are to be evaluated without the help of a well-equipped laboratory, with fewer expenses and within a short period of time. In a country like Nepal where laboratory facilities for direct evaluation of aerobic fitness is scanty, this method may be of great importance.

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7. References:

[1] Astrand PO, Rodahl K. *Textbook of Work Physiology.* New York: McGraw Hill Book Company, 1986.

[2] Bland, J.M. and Altman, D.G. Statistical method for assessing agreement between two methods of clinical measurements. *Lancet.* 1986, **1**: 307-310.

[3] Cetin, C., Karatosun, H., Baydar, M.L. and Cosarcan, K. A regression equation to predict true maximal oxygen consumption of taekwondo athletes using a field-test. *Saudi Med J.* 2005, **26**(5): 848 -50.

[4] Chatterjee, S. and Chakravarti, B. Comparative study of maximum aerobic capacity by three ergometries in untrained college women. *Jpn J Physiol.* 1986, 6: 151-162.

[5] Chatterjee, P., Banerjee, A.K., Majumdar, P. and Chatterjee, P. Validity of the 20 m multi stage shuttle run test for the prediction of VO_2 max in junior taekwondo players. *International Journal of Applied Sports* Sciences. 2006, **18**(1): 1-7.

[6] Chatterjee P, Banerjee AK, Das P, et al. A regression equation for the estimation of maximum oxygen uptake in Nepalese adult females**.** *Asian Journal of Sports Medicine.* 2010, **1**(1): 41-45.

[7] Chatterjee P, Banerjee AK, Das P, et al. A regression equation for the estimation of VO_2 max in Nepalese male adults. *Journal of Human Sport and Exercise.* 2010a, **5** (2):127-133.

[8] Chatterjee P, Banerjee AK, Das P, et al. A regression equation to predict VO_2 max of young football players of Nepal. *Int J Appl Sports Sci.* 2009, **21**(2): 113-121.

[9] Consolazio, C.F., Johnson, R.E. and Pekora, J. *Analysis of gas samples.* In: Samuel J, Hans field S, editors. *Physiological measurements of metabolic function in man.* 2nd ed. New York: McGraw Hill Book Company. 1963. pp. 507-10.

[10] Cooper, S.M., Baker, J.S., Tong, R.J., Roberts, E. and Hanford, M. The repeatability and criterion related validity of the 20-m multistage fitness test as a predictor of maximal Oxygen Uptake in Active Young Men. *Br J Sports Med* . 2005, **39**(4): 19.

[11] Das, S.K. and Bhattacharya, G. A comparison of cardiorespiratory fitness in non-athletes and athletes of eastern India. *Indian Journal of Physiology and Allied Sciences.* 1995, **49**: 16-23.

[12] Fox, E.L. A simple, accurate technique for predicting maximal aerobic power. *J. Appl. Physiol.* 1973, **35**: 914-16.

[13] Gibson, A., Broomhead, S., Lambert, M.I. and Hawley, J.A. Prediction of maximal oxygen uptake from a 20-m shuttle run as measured directly in runners and squash players. *J Sports Sc.* 1998, **16**(4): 331-5.

[14] Guerra, S., Ribeiro, J.C., Costa, R., Duarte, J. and Mota, J. Relationship between cardiorespiratory fitness, body composition and blood pressure in school children. *J Sports Med Phys Fitness*. 2002, **42**(2): 207-13.

[15] Leger, L.A. and Gadoury, C.. Validity of the 20 m shuttle run test with 1 minute stages to predict VO2 max in adults. *Can J Sports Sci.* 1989, **14**(1): 21-6.

[16] Leger, L.A., Mercier, D., Gadoury, C. and Lambert, J. The multi stage 20-m shuttle run test for aerobic fitness. *J Sports Sci.* 1988, **6**(2): 93-101.

[17] Mota, J., Guerra, S., Leandro, C., Pinto, A., Ribeiro, J.C. and Duarte, J.A. Association of maturation, sex, and body fat in cardiorespiratory fitness. *Am J Hum Biol.* 2002, **14** (6): 707-12.

[18] Portney LG, Watkins MP. *Foundation of clinical research, application to practice*. Norwalk (CT): Appleton & Lange. 1993, pp. 53-67.

[19] Slonim, N.B., Gillespie, D.G. and Harold, W.H. Peak oxygen uptake of healthy young man as determined by a treadmill method. *J Appl Physiol.* 1957, **10**: 401-404.

[20] Suminski, R.R., Ryan, N.D., Poston, C.S., and Jackson, A.S. (2004). Measuring aerobic fitness of Hispanic youth 10 to 12 years of age. *Int J. Sports Med.* 2004, **25**(1): 61-7.

[21] Vicente-Rodriguez, G., Jimenez-Ramirez, J., Ara, I., Serrano-Sanchez, J.A., Dorado, C. and Calbet,, J.A. Enhanced bone mass and physical fitness in prepubescent badmintoners. *Bone.* 2003, **33**(5): 853-9.

[22] Vicente-Rodriguez, G., Dorado, C., Perez-Gomez, J., Gonzalez-Henriquez, J.J., and Calbet, J.A. Enhanced bone mass and physical fitness in young female handball players. *Bone.* 2004, **35**(5): 1208-15.

[23] Wong, T.W., Yu, T.S., Wang, X.R. and Robinson, P. Predicted maximal oxygen uptake in normal Hong Kong Chinese schoolchildren and those with respiratory diseases. *Pediatric Pulmonol.* 2001, **31**(2): 126-32.