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PREDICTION OF MAXIMAL OXYGEN CONSUMPTION FROM BODY MASS, HEIGHT AND BODY SURFACE AREA IN YOUNG SEDENTARY SUBJECTS

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Abstract : The study was aimed to establish prediction norms for maximal oxygen uptake (VO_2max) from age, body mass and body surface area (BSA) in young sedentary subjects of Kolkata, India. Students of 20–24 years (male = 40 and female = 40) were recruited by simple random sampling from University of Calcutta, Kolkata. Thirty participants from each sex were further randomly alloted to the "study group" and rest 10 participants to the "confirmatory group". Physical parameters were measured and VO_2max determination comprised of incremental bi-cycle exercise followed by expired gas analysis in Scholander micro-gas analyzer. Significant ($P<0.001$) correlation of VO_2max existed with age, body mass, body height and BSA. Prediction of VO_2max in the confirmatory groups using the norms obtained from different physical parameters depicted insignificant variation from the directly measured value of VO_2max. Among these equations VO_2max prediction from BSA was considered as the most valid one because of its highest correlation coefficient with VO_2max in both the sexes. Multiple regression equation for prediction of VO_2max from body mass and body height was also computed. The equation established from BSA is recommended as the most reliable and valid to predict VO_2max in the young sedentary subjects of Kolkata, India; and multiple regression equations are also recommended for cross-checking the value.

Key words : VO_2max body weight body surface area prediction norms

INTRODUCTION

Maximum oxygen uptake (VO_2max) reflects the amount of oxygen utilized by working muscles and is a globally accepted measure of cardiorespiratory fitness (1). It also largely depends on physical parameters (1).

Direct measurement of VO_2max is time consuming, expensive, laborious and requires high subject motivation (2–4). However, some indirect norms for prediction of VO_2max from different physical parameters, especially from body mass are available (5–9). These prediction norms are highly population specific and thus restricted their

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application. Every laboratory should have its own reference standard. Previous studies did not provide comprehensive analysis on relationship of all the physical parameters (viz, age, body mass, body height, BSA) and VO_2max, rather they emphasized on one or two physical parameters only (5–13). Moreover, attempt to establish prediction norms for VO_2max in the form of multiple regression analysis is not available.

The present investigation was therefore undertaken to establish the prediction norms for VO_2max from physical parameters among sedentary young healthy male and female university students of Kolkata, India.

METHODS

Selection of Participant

80 sedentary university students (male = 40, female = 40) belonging to age group of 20 to 24 years from the middle class socio-economic background were recruited for the study on the basis of simple random sampling from the post-graduate section of the University of Calcutta, Kolkata, India. Out of the 40 participants in each group, 30 individuals were further separated by simple random sampling method as "Study Group" on which the experiments were carried out to set up the norms, Later on, the 10 remaining participants, termed as "Confirmatory Group", were tested to evaluate the validity of the norms obtained from the Study Group. To avoid any bias in this later part of the study each subject's physical parameters were measured by one author while VO_2max was determined by another of the three authors. The subjects had no history of any major disease and were not under any physical conditioning program and or medication. The Ethics Committee of the University of Calcutta (Faculty of Science) had approved the study and each participant provided informed consent. All the experiments were performed in the Sports & Exercise Physiology Laboratory of University of Calcutta.

Age of each subject was calculated to the nearest year from the date of birth obtained from the University records. Body mass and body height were measured with a standard weighing machine that included a height measuring stand (Avery India Ltd., India), Body mass was measured to an accuracy of ± 0.250 kg and height to an accuracy of ± 0.50 cm. Body surface area (BSA) was calculated using DuBois equation (14) : **BSA (m^2) = (Body Height)$^{0.725}$ × (Body Weight)$^{0.425}$ × 0.007184.**

Preparation of Volunteers

The volunteers came to the laboratory in the morning at their convenience after having light break fast at least 2 to 3 hours prior to the test and refraining activity during that period. The entire experimental procedure was explained to the subjects to allay their apprehension.

Determination of Cardiorespiratory Fitness (VO_2max)

Muller's magnetic brake bicycle ergometer (model of Max Planck Institute of Work Physiology) was used for the study. All the subjects first performed a submaximal exercise at 60 and 50 watt intensity for males and females, respectively, for 5 minutes. Immediately after performing the submaximal exercise the intensity was increased to the first incremental intensity of 120 and 100 watt for males and females, respectively, and thereafter the intensity was increased by 30 watt every 3 minutes until the subject stopped due to exhaustion (2). In the present study $V0_2$max was considered to be achieved at the point where heart rate was greater than 180 beats/min and had leveled off. Subjects did not endure more than 8 minutes 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. The valve was connected to a Douglas Bag (150 l) with a standard corrugated rubber tube and the expired gas was collected in the last minute of final intensity of exercise recognized by signs of severe exhaustion and heart rate greater than 180 beats/min. Gas was collected in the second minute of the final workload if the subject showed signs of severe exhaustion. No gas collection was made in the first minute of the workload. The expired gas was measured in a wet gasometer (Toshniwal, Cat No CG 05.10) and the aliquots of gas samples were analyzed in a Scholander microgas analysis apparatus following the standard procedure (15). The peak heart rate was recorded manually from the time taken for 10 carotid pulsations immediately after cessation of exhaustive exercise.

All experiments were performed at a room temperature varying from 27 to 29°C and at a relative humidity ranging between 70 and 85 per cent.

Statistical analysis

Unpaired t-test was performed to test the significance of difference between mean values of age, body weight, height, BSA and VO_2max obtained in male and female groups. Pearson's product moment correlation was adopted to establish the relationship between two variables. Bland and Altman approach for limit of agreement was also performed (16). Simple and multiple regression analysis were adopted to establish the norm between physical parameters and VO_2max.

RESULTS

Age, body mass, body height, BSA and VO_2max of the study and confirmatory groups are shown in Table I. Prediction equations for VO_2max from corresponding physical parameters are tabulated in Table II. Predicted values of VO_2max based

TABLE I : Physical parameters and VO_2max of sedentary male and female university students in Kolkata.

Parameters	*Males*		*Females*	
	Study group (n=30)	*Confirmatory group (n=10)*	*Study group (n=30)*	*Confirmatory group (n=10)*
Age (years)	22.06±1.35	21.86±2.00	21.5±1.55	21.80±1.69
Body mass (kg)	55.50±6.01	54.67±7.03	48.93±4.12	48.01±5.68
Body height (cm)	165.10±3.90	166.00±4.61	156.76±4.35	155.86±5.61
BSA (m^2)	1.61±2.24	1.60±2.67	1.47±0.07	1.45±0.09
Absolute VO_2max (l/min)	2.20±0.24	2.20±0.36	1.61±0.30	1.54±0.41
Relative VO_2max (ml/kg/min)	39.52±2.91	40.31±3.60	32.79±3.90	32.15±4.16

All values are expressed as mean±Standard Deviation.

TABLE II : Simple prediction equations for VO_2max from different physical parameters.

Independent variable	*Category*	*Regression coefficient*	*Constant*	*Correlation coefficient (r)*	*SEE*	*Level of significance*
Age (yrs)	Male	0.10	–0.006	0.55	0.03	P<0.001
	Female	0.12	0.98	0.64	0.03	P<0.001
Body mass (kg)	Male	0.03	0.54	0.81	0.02	P<0.001
	Female	0.06	–1.33	0.76	0.02	P<0.001
Body height (cm)	Male	0.04	–4.41	0.66	0.02	P<0.001
	Female	0.06	–7.8	0.85	0.01	P<0.001
BSA (m^2)	Male	0.09	2.06	0.83	0.02	P<0.001
	Female	4.15	–4.49	0.97	0.003	P<0.001

TABLE III : VO_2max values obtained in confirmatory groups by direct measurement and from prediction equations (i.e., the norms established in the study).

Category	*Procedure*	*VO_2max*	
		l/min	*ml/kg/min*
Males (n=10)	Direct measurement	2.20±0.36	40.31±3.60
	From age	2.18±0.45	39.90±4.10
	From body mass	2.18±0.31	39.90±3.91
	From body height	2.23±0.32	40.80±3.46
	From BSA	2.20±0.36	40.31±4.17
Females (n=10)	Direct measurement	1.54±0.41	32.15±4.16
	From age	1.63±0.42	33.95±3.90
	From body mass	1.55±0.37	32.30±4.51
	From body height	1.55±0.39	32.30±4.68
	From BSA	1.53±0.34	31.82±3.64

All values are expressed as mean±Standard Deviation.

on age, weight, height and BSA did not vary significantly from their corresponding directly measured values of VO_2max (Table III).

DISCUSSION

All the physical parameters were well correlated with VO_2max indicating dependence of the later on physical parameters. Previous pertinent studies indicated body mass as the best predictor of VO_2max (5–7, 9–11). But in the present study body mass exhibited higher value of correlation coefficient (r=0.81) with VO_2max than height (r=0.66) in case of males, while females depicted lower value of correlation coefficient (r=0.76) between body mass and VO_2max than that of between height and VO_2max (r=0.85). However, highest values of correlation coefficient were obtained between VO_2max and BSA in both the sexes and hence BSA was considered as the most valuable predictor of VO_2max among all the physical parameters in the chosen population. But as BSA was computed from body mass and body height, therefore, application of BSA as independent variable for prediction of VO_2max appeared a bit complicated than using body mass or height as independent parameter for the same. The SEE of VO_2max while predicting from the currently established norms, were found to be substantially small enough in comparison with previous studies (5–13) to consider all these parameters, viz., body height, body mass and BSA as good predictors of VO_2max in the currently chosen population.

Moreover, in confirmatory groups, predicted VO_2max values exhibited statistically insignificant variation from the directly measured values of VO_2max in both sexes. Bland and Altman's method of limit of agreement approach also depicted that the mean difference between directly measured and predicted values from BSA were small enough (0.133±0.11 and 0.075±0.031 in males and females, respectively) in both the sexes (Fig. 1).

Comparison of our norms for prediction of VO_2max from body mass with other previously available norms depicted wide range of variation in mean and SEE (Fig. 2). Uth (3) and Uth et al. (4) hypothesized that VO_2max can be predicted from the ratio between resting and maximum heart rate among trained individuals and body mass acted as a proportionality factor in-between the sexes probably due to proportionately higher fat percentage among females. Malek et al. (8) recommended one multiple linear prediction equation for prediction of VO_2max from age, body mass, height, training hours per week, intensity of training and natural logarithm of years of training among aerobically trained females of USA. Despite considering six independent variables, the SEE (259 ml/min) was considerably large enough. Cardinal (10) proposed couple of formulae for prediction of VO_2max in epidemiological studies taking seven items of physical activity indices as independent parameters among Detroitian females of USA. Verma et al. (9, 11) in their studies proposed that physical characteristics are good predictors of maximal oxygen uptake in Indian males and more importantly they obtained highest value of correlation coefficient when body mass was considered as an independent parameter. This fact corroborates with the findings among males of present investigation, but their SEE (0.204–0.214 l/min) was more than the current observation, and thus the norms established in the current study can be considered to have better authenticity.

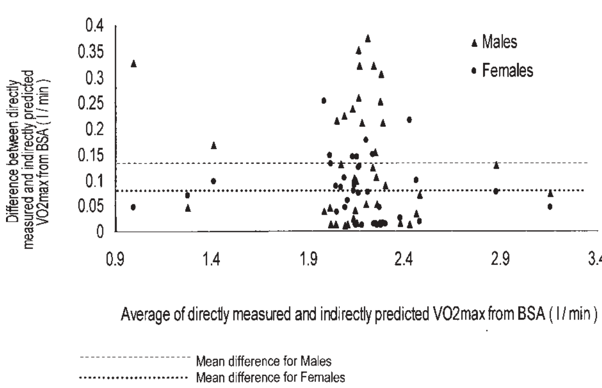

Fig. 1 : Results of Bland and Altman's analysis in the studied population.

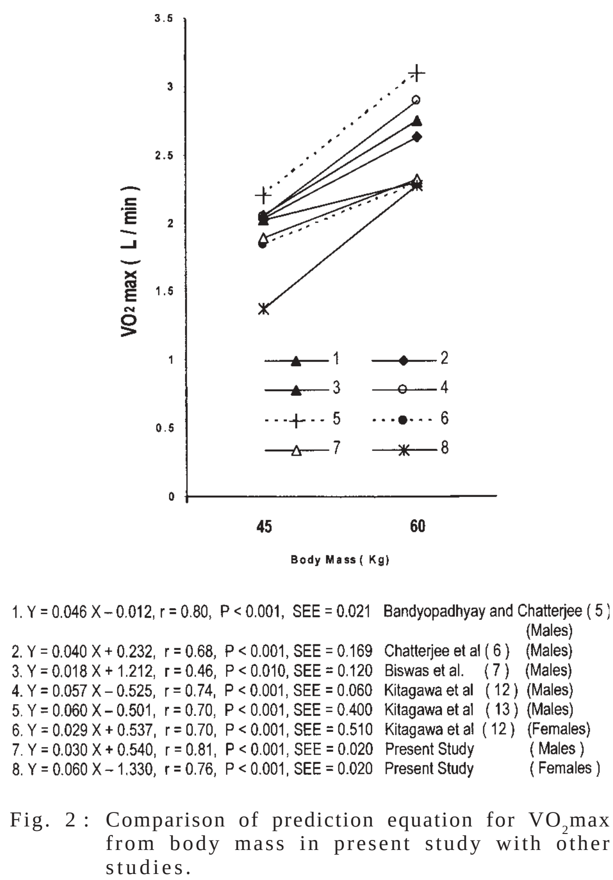

Fig. 2 : Comparison of prediction equation for VO_2max from body mass in present study with other studies.

As both body mass and body height were highly correlated with VO_2max in both the sexes, hence prediction of VO_2max from these two physical parameters were also attempted and revealed following norms in the form of multiple regression equation :

Males : VO_2max (L/min) = 0.014 × Body Mass +0.073 × Body Height – 10.627, R = 0.50, P<0.001, SEE = 0.208

Females : VO_2max (L/min) = 0.045 × Body Mass +0.026 × Body Height – 4.076, R = 0.64, P<0.001, SEE = 0.230

These multiple regression equations are more complicated than the simple ones and depicted higher values of SEE. Therefore, in both the sexes the simple prediction equation for VO_2max from BSA with considerably low SEE was found to be most reliable in this aspect.

Conclusion

From the present investigation it may be concluded that age, body mass, body height and BSA are good predictors of cardiorespiratory fitness in young sedentary subjects of Kolkata, India but BSA is the best among them. Therefore, the norm established from BSA is recommended as the most reliable, valid and well applicable to predict VO_2max in the studied population. More importantly multiple regression equations are also recommended for cross-checking the predicted value, whenever necessary.

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