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A study on the prediction of maximal oxygen consumption ($VO_{2\ max}$) among male and female medical college student population using bicycle ergometer

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Abstract
The maximal rate of oxygen uptake ($VO_{2\ max}$) is an important determinant of cardio-respiratory fitness and aerobic performance. Maximal oxygen uptake (VO_{2max}) is an important, independent predictor of cardiovascular health and mortality. The present study was conducted in the Dept. of Physiology, GSL Medical College, East Godavari Dist., Andhra Pradesh, India. The study was conducted to establish prediction norms for $VO_{2\ max}$ from physical parameters among sedentary young healthy student subjects (n = 72) consisting of male (n = 36) and female (n = 36) students of Medical College belonging to age group 18 – 24 years. The study was aimed to compare and correlate the measured parameters with the predicted parameters of $V{\cdot}O_{2max}$ using a sub maximal cycle ergometry test. The parameters studied were age, gender, height, weight, systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean arterial pressure (MAP). The predicted $VO_{2\ max}$ was calculated in male (n = 36) and female (n = 36) subjects during multistage sub maximal exercise test with bicycle Ergometer using the modified Astrand-Rhyming Nomogram. The present study results showed that mean heart beat rate, SBP and DBP variables can be identified as the good indicators on prediction of maximal oxygen consumption ($VO_{2\ max}$) using bicycle ergometer among males and female subjects though male individuals showed higher $VO_{2\ max}$ values of mean body weight, height compared to female subjects however, was statistically not significant. Future research should focus on the variables involved in the prediction equations by stratification of subjects to obtain a large range of values for the variable (s) investigated. It was not possible to do this with the subjects such as age, weight and height participating in this project because the variables used were not easily stratified.

Keywords: body weight, cardio-respiratory fitness, gender, heart rate, height, maximal rate of oxygen consumption ($VO_{2\ max}$)

Introduction

Aerobic power or maximum oxygen uptake ($VO_{2\ max}$) is the maximum rate at which oxygen is utilized by working muscles and is a globally accepted measure of cardio-respiratory (or aerobic) fitness [1, 2]. Maximal oxygen uptake ($VO_{2\ max}$) largely depends on physical parameters and is an important and independent predictor of cardiovascular health and mortality. The $VO_{2\ max}$ value is used as an evaluator of a person's ability to work, ability to perform in an athletic event and/or current health condition. It is usually determined using maximal or sub maximal exercise tests with treadmills, cycle ergometers or step tests. Other less popular methods also exist such as swim tests, walk tests and run tests, but these are not frequently used.

The measure of the maximal rate of whole body oxygen consumption during exercise ($VO_{2\ max}$) has a history dating back to the pioneering work of Hill and his colleagues [3]. Traditionally, $VO_{2\ max}$ has been interpreted as a measure of the maximal capacity of the cardio-respiratory system to acquire oxygen, circulate it to the working muscle, where muscle can the extract and utilize oxygen in mitochondrial respiration to meet the energy needs of muscle contraction.

The direct measurement of $VO_{2\ max}$ is time consuming, laborious, expensive and requires subject motivation [4-6]. Numerous procedures have been researched and validated to estimate $VO_{2\ max}$ from sub maximal exercises (like Treadmill, Cycle Ergometer and Field tests) or procedures not involving exercise at all.

The purpose of developing prediction equations is to provide a simpler means of determining a complex measurement by using variables that are easily measured. The selection of important variables that are likely to influence the $VO_{2\ max}$, along with good research techniques and equipment are important factors that affect the validity of the prediction equation [7].

Thus, to develop better prediction equations, various predictive tests have been devised to evaluate aerobic fitness which includes performance related measures, for example walking or running for a given time [8]. $VO_{2\ max}$ can also be estimated using a variety of methods involving maximal or sub maximal exercise tests or non exercise questionnaires. Sub maximal tests have certain advantages over maximal tests that do not require any specialized laboratory equipment, also test administrators require less training and the exercise intensity is realistic for most participants.

Sub maximal testing is a popular and effective way of evaluating cardio-respiratory (or aerobic) fitness (CRF) and is valuable in developing individualized exercise programs. In addition, periodic sub maximal testing provides a convenient way to monitor progress throughout an exercise program and educates participants about their potential risk for cardiovascular and other chronic diseases [9]. Non exercise methods of predicting $VO_{2\ max}$ are also useful and convenient, that require participants to simply answer a few questions and then compute a relatively accurate $VO_{2\ max}$ score using a multiple linear regression equation [10]. Sjostrand [11] and Astrand and Rhyming [8] were the first to develop sub maximal cycle ergometer protocols. Since then, researchers have continued to develop methods of predicting $VO_{2\ max}$ from sub maximal workload using cycle ergometers.

Cycle ergometry is a method of testing in which cycle ergometry allows selection of precise work rates which can be expressed with appropriate units of power (e.g., kgm / min); cycle ergometers require minimal space and are easy to transport; cycle ergometer exercise is a non weight-bearing activity that is usually well tolerated by individuals with orthopaedic or other physical limitations; and heart rate (HR), blood pressure, and electrocardiographic data are easily collected during the test protocol. In addition, sub maximal cycle ergometer tests provide relatively accurate estimates of CRF in a variety of populations [12].

The present study investigation was conducted to establish prediction norms for $VO_{2\ max}$ from physical parameters among sedentary young healthy male and female students of Medical College selected as subject group for the study.

Materials and Methods

The present study was carried out in the Department of Physiology, GSL Medical College, East Godavari Dist., Andhra Pradesh, India. A total of n = 72 subjects of age group ranging between 18 - 24 years selected were MBBS students of our Medical college. All the subjects were informed about the study protocol and written consent was obtained from them to participate in the study prior to the procedure. Permission from Head of the Department was taken. The approval for the study was obtained from the Ethical committee of the institution. Out of the total n = 72 subjects selected for the study, n = 36 were males and n = 36 were female subjects. A structured proforma was designed to record the personal data of the selected subjects regarding their name, age, gender, height, weight, personal history like smoking with duration and quantity, any history of lung disease, history of persistent cough, etc.

The inclusion criteria included normal sedentary students of GSL Medical College between age group 18 – 24 years.

Exclusion criteria included individuals having exertional cardio-respiratory disorders, individuals having no past history of musculoskeletal disorders or any other physical ailment.

Prior to reporting to the laboratory testing, the subjects were given instructions, to drink plenty of water and avoid vigorous exercise the day of testing, and not to consume food, alcohol, caffeine, or tobacco products three hours before testing [2].

The instruments used were, Aerofit upright bicycle ergometer, model SMAG350U for exercise testing, modified Astrand-Rhyming Nomogram for prediction of $VO_{2\ max}$.

Procedures

When the participants reported to the laboratory, they were informed verbally about the purpose of the research, the procedures used and the possible discomforts and risks of the study. During the first session with each subject the information sheet was completed and information regarding age, gender, weight and height was obtained. All questionnaires, health screening, physical measurements and physiological testing were completed in one session. Following the completion of the medical history questionnaire, the subjects eligible to participate were asked to read and sign the informed consent. Before collection of the data, the subject participants were given a brief explanation of all test protocols and completed the modified Physical Activity Recall Questionnaire (L0-PAR). The total scores and exercise section scores of the Lo-PAR were recorded as predictor variables for the subsequent statistical analysis.

The subjects were instructed to start cycling adjusting the rate to 60 rpm. His / her pulse rate was counted every minute, during the last 30 sec of each minute. The exercise was continued for 5 minutes. If the pulse rate continued to rise each minute by more than 5 beats, the exercise was continued for the next minute i.e., the 6th minute and the average pulse rate of the last 2 minutes was taken as the steady state pulse rate at the given workload. If the steady pulse rate calculated as above with a given load is still less than the target heart rate of the subject, the work load was increased and the entire test was repeated again after giving 20 min rest to the participant. This was continued until the target pulse rate was achieved and the particular workload was noted.

From the target pulse rate and corresponding work load, the predicted $VO_{2\ max}$ was calculated using the modified Astrand-Rhyming Nomogram. The $VO_{2\ max}$ was estimated from the heart rate during multistage sub maximal exercise test with bicycle Ergometer using the modified Astrand-Rhyming Nomogram. This modified approach is a more acceptable form because it was validated using the original method.

The $VO_{2\ max}$ was corrected for the age by using the formula given by Siconlofi *et al.* [13] as given below:

$$CVO_{2\ max} = 0.348\ (X_1) - 0.035\ (X_2) + 3.011.$$

(Where, C is the corrected $VO_{2\ max}$ (L / min), X_1 is $VO_{2\ max}$ obtained from Astrand-Rhyming Nomogram, X_2 is the age of the subjects in years).

Statistical analysis

The data was statistically analyzed by using the SPSS software (version 12.0) and by applying Student's t-test.

Results

The heart rate noted at the 6th min was considered as target heart rate, change in BP was also measured during each min of the graded exercise. $VO_{2\ max}$ was obtained by intercepting work load (kpm / min) on the right side scale with the target heart rate (beats / min) on the left side scale in the Modified Astrand-Rhyming Nomogram by drawing a straight line. The $VO_{2\ max}$ was obtained by using modified Astrand-Rhyming Nomogram, applying the formula suggested by Siconlofi *et al*. [13]. The $VO_{2\ max}$ is generally expressed as ml / kg / min. According to the results predicted $VO_{2\ max}$ is L / body weight. The predicted $VO_{2\ max}$ is converted to standard form (ml / kg / min) by the equation $X_2 – X_1$ X 1000 / BM. Where, X_1 is predicted $VO_{2\ max}$ and BM is the body mass. The individuals taken for the study were MBBS students of age group between 18 – 24 years with no significant physical activity, otherwise called sedentary life style.

Attempts were made to compare $VO_{2\ max}$ and its correlation with other parameters measured. But in the present study observations recorded showed that $VO_{2\ max}$ reflects physiological principles. The data of the anthropometric parameters of male and female subjects is presented in Table 1. The data shows that there is no significant difference observed in the age of two group subjects studied. While, there was difference observed in the parameters such as height, weight, systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean arterial pressure (MAP) in male and female subjects. The parameters were relatively high in male subjects compared to female subjects. However, the difference was statistically not significant.

Table 1: Mean ± SD values of measured parameters of both sedentary male and female subjects

Sr. No	Parameters	male (n=36)	female (n=36)
		Mean ± SD	Mean ± SD
1	Age (yrs)	22.06 ± 1.72	22.01 ± 1.22
2	Height (cm)	175.23 ± 6.1	158.02 ± 4.1
3	Weight(Kg)	59.9 ± 3.19	54.45 ± 4.65
4	Pulse/min	73.4 ± 4.6	68.9 ± 5.2
5	SBP (mmHg)	109.6 ± 7.9	105.17 ± 7.21
6	DBP (mmHg)	71.3 ± 4.65	63.51 ± 7.91
7	PP (mmHg)	39.3 ± 6.54	37.95 ± 4.86
8	MAP (mmHg)	82.1 ± 6.19	75.8 ± 6.24

The data in the Table 2 shows relation between $VO_{2\ max}$ and $CVO_{2\ max}$ in male and female subjects. The difference between mean $VO_{2\ max}$ (L) and mean $CVO_{2\ max}$ (L) in male subjects was observed to be higher compared to female subjects.

Table 2: Shows relation between $VO_{2\ max}$ and $CVO_{2\ max}$ in the both male and female subjects

Group	Mean age (yrs)	Mean $VO_{2\ max}$ (L)	p value (<0.001)	Mean $CVO_{2\ max}$ (L)	p value (< 0.001)
Male (n = 36)	22.06	3.0	< 0.001	3.1	< 0.001
Female (n = 36)	21.01	2.6	< 0.001	2.9	< 0.001

The data of anthropometric parameters presented in the Table 3 shows changes in parameters observed before and after exhaustive exercise in male and female subjects. The pulse rate, SBP, DBP in male subjects was observed to higher when compared to female subjects. Statistical analysis data showed statistically significant difference in pulse rate, SBP, DBP.

Table 3: Shows changes in parameters before and after exercise in the male and female subjects

Parameters	Male (n=36) Mean ± SD	Female (n=36) Mean ± SD
Before Exercise Pulse / min	73.9 ± 5.4	68.8 ± 6.3
SBP (mmHg)	107.6 ± 8.1	104.4 ± 6.10
DBP (mmHg)	69.8 ± 9.1	61.89 ± 7.98
After Exercise Pulse / min	168.0 ± 8.3	162.0 ± 9.7
SBP (mmHg)	154 ± 5.2	142 ± 7.9
DBP (mmHg)	58 ± 6.9	55 ± 5.1

The data in the Table 4 shows the changes in the $VO_{2\ max}$ and its relation with age, body weight and gender. There was no statistically significant difference in age and mean body weight (Kg), mean $VO_{2\ max}$ (L) and Mean $CVO_{2\ max}$ (L) in male subjects though the values were higher compared to female subjects.

Table 4: The changes in the $VO_{2\ max}$ in both male and female subjects in relation to age, body weight and target heart rate

Group	$VO_{2\ max}$ in L / body weight	$VO_{2\ max}$ in ml / kg / min	Age in years (18 - 24)	Body weight (kgs)	Target Heart Rate (THR) beats / min
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Male (n=36)	3.09 ± 0.19	50.84 ± 2.98	22.06 ± 1.6	59.9 ± 3.19	168 ± 8.3
Female (n=36)	2.61 ± 0.26	45.05 ± 3.92	21.01 ± 1.4	56.45 ± 5.19	162 ± 9.7

Discussion

In the present study, it was predicted $VO_{2\ max}$ in male (n = 36) and female (n = 36) subjects belonging to the same age group 18 - 24 years using sub maximal bicycle ergometer protocol. In this study an attempt was made to compare and correlate the measured parameters with the predicted parameters if differences existed in the predicted physical work capacity values. In this study, male individuals showed more $VO_{2\ max}$ compared to female subjects, which was statistically significant (p< 0.001). The predicted $VO_{2\ max}$ obtained in this study matched the measured $VO_{2\ max}$ using direct procedures in the same age group subjects.

Comparison of present study predicted $VO_{2\ max}$ from body weight with other previously available norms showed a wide range of variation in mean and SD values.

Uth *et al*. [6] hypothesized that $VO_{2\ max}$ 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 both the genders probably due to proportionately higher fat percentage among females. Malek *et al*. [14] study recommended one multiple linear prediction equation for prediction of $VO_{2\ max}$ 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. Earlier researchers 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 [15]. This fact corroborates with the findings of the present study results. All the physical parameters were well correlated with VO2 max indicating dependence of the later on physical parameters. Previous pertinent studies indicated body mass as the best predictor of $VO_{2\ max}$ [15 - 20].

Absolute values of $VO_{2\ max}$ are typically 40 - 60% higher in men than in women. Obviously, this difference may be due to the variance in body weight and lean body mass between men and women. A more accurate comparison of maximal oxygen uptake between men and women would use the relative measure. Earlier research studies have shown that the average young untrained male will have a $VO_{2\ max}$ of approximately 3.5 litres / minute (absolute) and 45 ml / kg / min (relative). The average young untrained female will score $VO_{2\ max}$ of approximately 2.0 litres / minute and 38 ml / kg / min. The data of anthropometric parameters observed before and after exhaustive exercise in male and female subjects showed that the pulse rate, SBP, DBP in male subjects was observed to higher when compared to female subjects, and noted statistically significant difference in pulse rate, SBP, DBP.

The data showed changes in the $VO_{2\ max}$ and its relation with age, body weight and gender however, showed no statistically significant difference in age and mean body weight (Kg), mean $VO_{2\ max}$ (L) and Mean $CVO_{2\ max}$ (L) in male subjects though the values were higher compared to female subjects. The present study results showed that male subjects had more $VO_{2\ max}$ compared to female subjects in mean age and body weight, while statistically significant difference was observed in pulse rate, SBP, DBP. The maximum aerobic power routinely cannot be measured and also advisable for $VO_{2\ max}$ estimation. There is a difference of opinion existing among various workers as regards accuracy of predicting $VO_{2\ max}$ from the data recorded during the sub maximal exercise test. The standard error of such prediction using Astrand's Nomogram is 10% in relatively well trained individuals of same age but up to 15% in moderately trained individuals of different ages when age related factor was applied.

Conclusion

The present study results showed that mean heart beat rate, SBP and DBP variables can be identified as the good indicators on prediction of maximal oxygen consumption ($VO_{2\ max}$) using bicycle ergometer among males and female subjects though male individuals showed higher $VO_{2\ max}$ values of mean body weight, height compared to female subjects however, were as statistically not significant. Future research should focus on the variables involved in the prediction equations in large population studies. Based on this information the Astrand-Rhyming test method would be recommended.

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