Original Article

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Measured and Predicted Maximal Oxygen Consumption (VO_2max) in Healthy Young Adults: A Cross-Sectional Study

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Abstract:

Objective: Maximal oxygen consumption (VO_2max) can be estimated using maximal or sub-maximal tests, by direct or indirect methods.The Queen's College Step Test (QCT) is used very frequently to estimate VO_2max due to its simple, safe, quick and feasible approach. Originally the QCT was developed for the white race population, which is different from the Indian population in terms of ethnicity. So the present study was conducted to validate the applicability of the QCT to indirectly estimate VO_2max in Indian adults.

Material and Methods: A total of 419 apparently healthy students (male and female) were recruited for the study by the RUHS College of Medical Sciences (RUHS-CMS), Jaipur from January 2019 to March 2020 by random number table generator sampling. Direct estimation of VO_2max was performed by sub-maximal exercise testing on a treadmill using a gas analyzer, while VO_2max was indirectly predicted by the standard QCT protocol. The collected data were entered into Microsoft Excel and analyzed using unpaired student t-test, analysis of variance (ANOVA), and regression analysis.

Results: The average directly measured VO_2max (ml/kg/min) in males was 45.30±7.35, and for women was 35.71±5.29, and predicted by the QCT was 49.01 for males and 38.83±5.30 for females. The difference between the measured and predicted mean VO_2max (PVO_2max) values was statistically significant (p-value<0.05).

Conclusion: In this study, actual VO_2max was lower than the predicted VO_2max from the QCT. The results of this study suggest that a new equation derived from the present data, recommended to assess VO_2max using QCT in the Indian population, especially when large numbers of participants need to be tested in the absence of a well-equipped laboratory.

Keywords: cardiorespiratory fitness, direct method, gas analyzer, maximal oxygen consumption, Queen College's Step Test

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Introduction

Maximum oxygen uptake (VO_2max) measures the largest amount of O_2 an individual can transfer to to the exercise muscles during hard work. VO_2max reflects the amount of oxygen used by active muscles. VO_2max is expressed in liters/min as an absolute value or in milliliters/kg/min as a relative VO_2max. It is considered globally the gold standard for measuring the cardio-respiratory fitness of the individual.[1]

A person's VO_2max can be estimated using maximal or sub-maximal tests, by direct or indirect methods.[2] The direct method or (laboratory method) measures an individual's expired gases for analysis of pulmonary ventilation, inspiratory oxygen, and expired carbon dioxide. Direct measures accurately determine a person's higher oxygen consumption by breathing through air analysis. Indirect methods, which include field tests, measure a person's aerobic strength based on heart-rate, distance traveled, or test duration when a specific procedure is used.[3]

The decision to use a sub-maximum or maximum exercise test depends on the availability of appropriate equipment. A maximum exercise test is not always possible, as it may require the individual to exercise to the point of complete exhaustion. It may also require medical supervision and emergency equipment. Hence, sub-maximal tests are usually relied upon to assess cardio-respiratory fitness, thus providing information about an individual's response to sub-maximal exercise over time in a controlled environment, thus modifying the exercise prescription. It would be a good alternative to opt for a simple indirect procedure to assess VO_2max, to assess cardio-respiratory fitness in this area and also in the absence of a suitable laboratory.[4]

There are different modes used for exercise testing, including field testing, treadmill testing, bicycle ergometer testing, and stepping testing. Sub-maximal tests are classified as predictive tests or performance tests. Sub-maximal predictive testing can also be divided into treadmill testing and field testing.[5] The Queen's College Step Test (QCT) is a field test that requires a step of 16.25 in height. Being inexpensive and requiring minimal use of equipment, it can be conducted in a given population to determine the fitness index, VO_2max, when sophisticated equipment is not available. The QCT is one of the popular indirect field tests for prediction of VO_2max.[6]

Originally, the QCT was developed for the white race population, which is different from the Indian population in terms of ethnicity. It should also be considered that the Indian population differs from the Caucasian population in many respects, such as body stature, lifestyle, diet and nutrition, levels of physical activity that could directly or indirectly influence the maximum oxygen consumption.[7]

Cardiorespiratory fitness has positive effects on depression, anxiety, and mood swings associated with higher academic performance. The lifestyle of medical students has became unhealthy and physically inactive during the course of studies. There is a need for students to assess their cardiorespiratory fitness. VO_2max reaches maximum values between the ages of 18-30, and decreases progressively after that age.[8] VO_2max is an internationally accepted parameter for assessing cardio-respiratory fitness, but the determination of VO_2max is restricted to well-equipped laboratories due to its exhausting, dangerous and complicated experimental protocol. Various tests are available in the west population, but not in Indian population. Very few studies[9,10,11] have been conducted in India using a direct method to estimate VO_2max. Hence, this study was designed to estimate VO_2max with the direct method and compare the results of the direct and indirect methods. The present study was designed to evaluate the QCT, and evaluate the results with the direct method for Indian population.

Material and Methods

The present study was conducted after getting approval from the Institutional Ethics Committee (Approval letter no. RUHS-CMS/Ethics Comm/2018148/dated-2118/12/)

Study design: cross-sectional.

Study place: Research Laboratory in the Department of Physiology at RUHS College of Medical Sciences, Jaipur.

Study duration: All the participants were selected from the RUHS-CMS, Jaipur from January 2019 to March 2020.

Sample size: 419

Sampling: Random number table generator

Inclusion criteria: Young medical students, either gender, age18-25 years.

Exclusion criteria: History of hospitalization in the previous 3 months, smokers and alcoholics, individuals suffering from chronic diseases such as hypertension, diabetes, cardio-vascular diseases such as coronary artery disease or peripheral arterial disease, respiratory diseases such as asthma, emphysema, or bronchitis, muscular-skeletal diseases such as coliosis or rheumatoid arthritis, and students who regularly exercised or did yoga.

Preliminary information about the aim and purpose of the study, the test procedure, method of testing, and instructions on how to perform the test was given through the participant information sheet (PIS) then the subjects was recruited into the study after signing the consent form (ICF).

Data collection

Anthropometric data: Height and weight were measured following the National Health and Nutrition Examination Survey (NHANES) methods, and body mass index (BMI) was also calculated. The BMI of each subject was calculated as weigh in kg divided by height in meters squared.[13]

Physical activity: Physical activity was assessed using the Global Physical Activity Questionnaire (GPAQ).[14]

VO_2max estimation using a direct method (gas analyzer)

VO_2max was measured using a direct method, namely the AD instruments gas analyzer (model-ML206), as follows: The subject was asked to come in the morning or 23-hours after a meal. The graded exercise test protocol was first explained and demonstrated to the subject. The subject was asked to put on a mask which was connected to the gas analyzer which measures the total amount of gases (O_2 and CO_2) inhaled and exhaled during the test.The second evaluation test was the treadmill graded exercise test, in which the subject was asked to walk on a level grade for 3 minutes, followed by jogging at their chosen speed (b/w 4.3–7.5 mph) on a level grade for 3 minutes and then at a constant speed. The incline on the treadmill was increased by 2.5% every minute until the subject became too tired to continue the exercise. The device was connected to a screen that showed various values at every 10 seconds.[15]

VO_2max by indirect method QCT

The test protocol was explained to the subject and demonstrated. The step protocol was as follows: both feet on the floor, first foot on the step, second foot up the step, both feet on the step, first foot on the floor, and finally second foot on the floor. The subject was asked to perform the test for 3 minutes. The subjects steps up and down on the step at a rate of 22 step/minute for females and at 24 steps/minute for males. At the end of the test, the examiner records the number of pulse of subjects between the 5^{th} and 20^{th} seconds. The pulse rate per minute was calculated by multiplying it by a factor of 4. The VO_2max was then calculated using the following formula:[10]

Male: VO_2max (ml/kg/min) = 111.33–(0.42 x pulse rate in beats/min)

Female: VO_2max (ml/kg/min) = 65.81–(0.1847 x pulse rate in beats/min)

Statistical analysis

All data are presented as mean±standard deviation. The Kolmogorov–Smirnov test was performed to test for normality of outcome variables. Unpaired t-test was used to calculate the differences between the mean values of measured and predicted VO_2max. The coefficient of determination (R^2) was determined between the VO_2max values expected from the sub-maximal test programs and the VO_2max values measured from the direct method using a gas analyzer. To establish a mathematical relationship between the independent (pulse rate) and dependent variables (VO_2max), simple linear regression was used. Regression analysis and analysis of variance (ANOVA) were used to identify the impact of the pulse rate (beats/minute) on VO_2max (ml/kg/min) in males and females. A new equation was derived using regression analysis to accurately and reliably estimate VO_2max in the population studied. The level of significance was set at p-value<0.05.

Results

Table 1 shows that there were no statistically significant differences in the ages, body mass indexes (BMI) or pulse rates between the two groups. (p-value>0.05) The mean VO_2max was significantly higher in the male subjects than in the female. (p-value<0.05)

Table 1 Descriptive statistics of male and female subjects

Parameters	Gender	n	Mean±S.D.	p-value
Age	Male	275	20.34±2.02	0.56
	Female	144	20.22±2.02	
Weight (kg)	Male	275	65.45±9.68	<0.01
	Female	144	54.28±8.54	
Height (cm)	Male	275	172.70±5.61	<0.01
	Female	144	159.99±5.50	
BMI (kg/m^2)	Male	275	21.94±2.99	0.06
	Female	144	21.21±3.09	
Physical activity (METs)	Male	275	1,433.82±721.98	<0.01
	Female	144	909.58±431.74	
Pulse rate after exercise (beats/minute)	Male	275	148.29±17.25	0.49
	Female	144	146.94±21.83	
VO_2max (ml/kg/min) Direct method	Male	275	45.30±7.35	<0.01
	Female	144	35.71±5.29	
VO_2max (ml/kg/min) QCT	Male	275	49.01±7.2	0.02
	Female	144	45.30±7.37	

S.D.=standard deviation, BMI=body mass index, METs=metabolic equivalents of task, VO_2max=maximum oxygen uptake, QCT=The Queen's College Step Test

Table no 2 shows a comparative analysis of VO_2max using direct and indirect methods. A significant difference (p-value<0.05) was found for VO_2max estimation amongst subjects using the direct & indirect methods.

Table 3 shows a significant association between the pulse rate and VO_2max. was found for the pulse rate of males on their VO_2max. To establish a mathematical relationship between the independent (pulse rate) and dependent variable (VO_2max), simple linear regression was applied. The value of adjusted R^2 was 0.886 for the VO_2max. Henceforth, it can be stated that the pulse rate of the male subjects was able to explain the 88.6% variance of their VO_2max using direct method. Since the p-value obtained from the ANOVA table was less than 0.05, the proposed model was found to fit.

Average VO_2max (ml/kg/min) in males = 104.832–0.401 × pulse rate

Table 4 shows a significant association between the pulse rate and VO_2max in females. To establish a mathematical relationship between the independent (pulse rate) and dependent variable (VO_2max), simple linear regression was applied. The value of adjusted R^2 was 0.555 for the VO_2max. Henceforth, it can be stated that the pulse rate of the female subjects was able to explain the 55.8% variance of their VO_2max using direct method. Since the p-value obtained from the ANOVA table was less than 0.05, the proposed model was found to fit.

Average VO_2max (ml/kg/min) in females = 62.338–0.181 × pulse rate

Discussion

The purpose of this study was to measure cardio-respiratory fitness by estimating VO_2max and compares the results obtained using VO_2max direct and predicted in healthy young adults within the age group of 18 to 25 years, to develop a new predictive equation for estimating VO_2max in the Indian population.

As Table 1 shows, there were no statistically significant differences in the ages, BMI or pulse rates between the male and female subjects. The mean VO_2maxes of the male and female subjects by the direct method were 46.83±9.48 and 35.94±9.8ml/kg/min, respectively, significantly higher in the male participants than the female participants, which is similar to a study, in which the mean VO_2maxes for male and female subjects were 39.5±11.28 and 32.74±12.82ml/kg/min, respectively. The results of another study[17] were similar to the present study, with the VO_2max in the male participants (51.76±3.8

Table 2 Comparative analysis of VO_2max using direct (gas analyzer) & indirect methods (QCT)

Paired sample T-test	n	Mean±S.D.	Std. error mean	t	df	p-value
VO_2max (ml/kg/min) direct method (gas analyzer)	419	42.01± 8.11	0.39645	-24.532	418	<0.01
VO_2max (ml/kg/min) Indirect method (Queen's College Step Test)	419	45.51±8.23	0.40207			

S.D.=standard deviation, t=t-score, df=degrees of freedom, p-value=significance<0.05

Table 3 Regression analysis to identify impact of pulse rate (beats/minute) on VO_2max (ml/kg/min) using the direct method (gas analyzer) in males

Model summary						
Model	**R**	**R^2**	**Adjusted R^2**	**S.E. of the estimate**		
1	0.942[a]	0.887	0.886	2.47820		
a. Predictors: (constant), pulse rate (beats/minute) male						
ANOVA[a]						
Model		**Sum of squares**	**df**	**Mean square**	**F**	**p-value**
1	Regression	13,142.993	1	13,142.993	2,140.042	<0.01
	Residual	1,676.620	273	6.141		
	Total	14,819.614	274			
a. Dependent variable: vO_2max(ml/kg/min) direct method(gas analyzer) male						
b. Predictors: (constant), pulse rate (beats/minute) male						
Coefficients[a]						
Model		**Unstandardized coefficients**		**Standardized coefficients**	**t**	**p-value**
		B	**S.E.**	**Beta**		
1	(Constant)	104.832	1.295		80.931	<0.01
	Pulse rate (beats/minute) male	-0.401	0.009	-0.942	-46.261	<0.01
a. Dependent variable: VO_2max (ml/kg/min) direct method (gas analyzer) male						

R^2=coefficient of determination, df=degree of freedom, t=t-score, B=unstandardized coefficients, Beta=standardized coefficients, S.E.=standard error, F-value=a value by F-test (The F-test for linear regression tests whether any of the independent variables in a multiple linear regression model are significant

ml/kg/min) significantly higher compared to the VO_2max in the female participants (44.07±4.2 ml/kg/min). The mean VO_2maxes in the present study were slightly higher than those found in the previous studies but there were differences between males and females in both studies. Males normally have better cardio-respiratory fitness due to hormonal influences and physiological and behavioral factors, i.e. men have higher blood hemoglobin levels, lower body fat percentages, higher lean muscle mass, larger heart size, higher oxygen carrying capacity, maximum heart rates, maximal stroke volumes and increased involvement in physical activity. In our study, the mean±S.D. of directly measured VO_2max (ml/kg/min) in men was 45.30±7.35 against 35.71±5.29 in females. The mean standard deviation predicted by the QCT equation for VO_2max for men was 49.01 and for women 38.83±5.30. Similar results were seen in another study.[18] Koley et al.[19] determined the VO_2max values of college boys using the Queen's varsity step test and reported VO_2max values of 48.74±8.74 ml/kg/min.

As can be seen in Table 2, the difference between the mean values of VO_2max measured directly and those predicted indirectly (PVO_2max) was statistically significant (p-value<0.05). These data are similar to those found in a study by Chattarji in the same age group, in which measured VO_2max was lower than the predicted VO_2max of QCT, suggesting that the prediction equation is not applicable to

Table 4 Regression analysis to identify the impact of pulse rate (beats/minute) on VO_2max (ml/kg/min) using direct method (gas analyzer) in females

Model summary						
Model	**R**	**R^2**	**Adjusted R^2**	**S.E. of the estimate**		
1	0.747[a]	0.558	0.555	3.53521		
a. Predictors: (constant), pulse rate (beats/minute) female						
ANOVA[a]						
Model		**Sum of squares**	**df**	**Mean square**	**F**	**p-value**
1	Regression	2,237.043	1	2,237.043	178.996	<0.01
	Residual	1,774.673	142	12.498		
	Total	4,011.716	143			
a. Dependent variable: VO_2max (ml/kg/min) direct method (gas analyzer) female						
b. Predictors: (constant), pulse rate (beats/minute) female						
Coefficients[a]						
Model		**Unstandardized coefficients**		**Standardized coefficients**	**t**	**p-value**
		B	**S.E.**	**Beta**		
1	(Constant)	62.338	2.011		30.991	<0.01
	Pulserate (beats/minute) female	-0.181	0.014	-0.747	-13.379	<0.01
a. Dependent variable: VO_2max (ml/kg/min) direct method (gas analyzer) female						

R^2=coefficient of determination, df=degree of freedom, t=t-score, B=unstandardized coefficients, Beta=standardized coefficients, S.E.=standard error, F-value=a value by F-test (The F-test for linear regression tests whether any of the independent variables in a multiple linear regression model are significant

the population in the current study because these regression equations were formulated on the basis of normative data obtained from the white race population.[9] Siamilar findings were observed in a study by Siahkouhian, which found that VO_2max was overestimated by the QCT in the Iranian population.[20]

Tables 3 and Table 4 show the significant results of regression analysis of impact of pulse rate (beats/minute) on VO_2max (ml/kg/min) using a direct method in males and females. In earlier study Khare D also found a correlation between pulse rate and VO_2max and concluded that good VO_2max is achieved if the pulse rate is low after excercise.[21] In another previous study Chattarji found that the original prediction equation of the QCT could not be applied to measure VO_2max due to poor agreement with the direct method, but with the modified equation it could be applied in Indian population to assess VO_2max, especially when a large number of participants without a well-equipped laboratory need to be tested. Buttar et al.[18] suggested in their study that the QCT in its original form gave overestimated results in the Indian population. QCT is the fastest, easiest, safest and most feasible way to measure VO_2max until a new modified equation is developed to measure VO_2max for the Indian population.

In a previous study, different results regarding the influence of height on the estimation of VO_2max by the

QCT. John studied differences in maximum oxygen uptake in 101 Indian adults and developed a prediction equation for it, as the equations used at the time were derived from western population studies. Their study found that VO_2max in the Asian Indian population was significantly lower than in the western population. They reported that VO_2max was influenced by race and that Indians differed significantly from the white population in their body length, nutrition, physical activity, environment, and socioeconomic factors. All the reasons mentioned above could have contributed to similar results obtained in the present study.

Previously, we used Caucasian population prediction equations to predict VO_2max in Indians, believing them to be the most appropriate. In this study, we construct linear regression equations to predict VO_2max and pulse rate for a healthy Indian population.

The following equation, derived based on current data, will best predict aerobic fitness in healthy young adults, male and female, in India.

VO_2max (mL/kg/min) in males = 104.832–0.401 × pulse rate (beats/minute)

VO_2max (mL/kg/min) in females = 62.338–0.181 × pulse rate (beats/minute)

Conclusion

In this present study actual VO_2max was lower than the predicted VO_2max from the QCT. Therefore, our newly derived equations are recommended for the application of the QCT as a valid method for correct and accurate assessment of cardio-respiratory fitness in terms of VO_2max of both sexes in healthy young Indian adults, especially when large numbers of participants need to be tested in the absence of a well-equipped laboratory. With the help of measured VO_2max we can determine physical fitness in students and create awareness about the importance of physical activity and life style modifications.

Limitations

The sample size was small and the study results are not applicable to all age groups. Therefore, more studies should be carried out with larger sample sizes including different age groups.

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Conflict of interest

No conflicts of interest.

References

1. Shephard RJ, Allen C. The maximum oxygen intake. An international reference standard of cardio respiratory fitness. Bull World Health Organ 1968; 38:757-64.
2. Ross R, Blair SN, Arena R, Despres JP, Franklin BA, Haskell WL et al. Importance of assessing cardio-respiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. Circulation 2016;134:653-99.
3. Buttar KK, Saboo N, Kacker S. Maximal oxygen uptake (VO_2max) and its estimation methods. Int J Phy Educ Sports Health 2019;6:24-32.
4. Leger LA, Mercier D. The multistage 20-metre shuttle run test for aerobic fitness J Sports Sci 1988;6:93-101.
5. Bassett D R, Howley E T. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc 2000;32:70-80.
6. Chatterjee S, Chatterjee P. Prediction of maximal oxygen consumption from body mass, height and body surface area in young sedentary subjects. Indian J Physiol Pharmacol 2006;50:181-6.
7. John N, Thangakunam B. Maximal oxygen uptake is lower for a healthy Indian population compared to white populations. J Cardiopulm Rehabil Prev 2011;31:322-7.
8. Van der GE, Takken T. Referencevalues for maximum oxygen uptake relative to body mass in Dutch/Flemish subjects aged

6-65 years: the LowLands fitness registry. Eur J Appl Physiol 2021;121:1189-96.
9. Nitin YM, Sucharita S, Madhura M, Thomas S, Sandhya TA. VO_2max in an Indian population: a study to understand the role of factors determining VO_2max. Indian J Physiol Pharmacol 2013;57:87-94.
10. Chatterjee S, Chatterjee P. Validity of Queen's College Step Test for use with young Indian men. Br J Sports Med 2004;38:289-91.
11. Chatterjee S, Chatterjee P. Validity of Queen's College Step Test for estimation of maximum oxygen uptake in female students. Indian J Med Res 2005;121:32-5.
12. Anjana RM, Pradeepa RG, Das AK, Deepa M. Physical activity and inactivity patterns in India-results from the ICMR-INDIAB study (phase-1). Int J Behav Nutr Phys Act 2014;11:11-26.
13. CDC. National Health and Nutrition Examination Survey (NHANES)-Anthropometry procedure manual. California: Createspace; 2007.
14. World Health Organization. WHO STEPS surveillance manual: the WHO STEP wise approach to chronic disease risk factor surveillance. Geneva: WHO; 2005.
15. Verhs PR, Geordge JD. Sub maximal treadmill exercise test to predict VO_2max in fit adults. Meas Phys Educ Exerc Sci 2007;11:61-72.
16. Shah H, Prajapati T, Singh SK. Association of body mass index with VO_2max in Indian adults. Int J Basic Appl Physiol 2016;5:155-9.
17. Modala S, Kumar PS, Sugunakar M, Pradeep KBJ, Prediction of maximal oxygen consumption using bicycle ergometer among males and females in GSL student. Int J Basic Appl Med Sci 2015;5:271-75.
18. Buttar KK, Saboo N, Kacker S. Maximal oxygen consumption (VO_2max) estimation using direct & indirect methods in the Indian population: a pilot study. J Clin Diagnostic Res 2020; 14:6-8.
19. Koley S. Association of cardio-respiratory fitness, body composition and blood pressure in 'a' collegiate population of Amritsar, Punjab, India. Internet J Biol Anthropol 2007;1:13-16.
20. Siahkouhian M. Impact of height on the prediction of maximum oxygen consumption in active young men. J Appl Sci 2009;9:2340-3.
21. Khare D, Sharma M. To determine the correlation of recovery pulse rate and VO_2max on performance of QCT in young Indian females. Int J Med Health Res 2017;3:1-5.
22. Bolboli L, Siahkouhian M, Poorrahim, A, Narimani M, Ganji M, Barahmand U. Is cardiorespiratory fitness affected by height of young girls?. Pak J Biol Sci 2008;11:1510-3.