

# Maximum Oxygen Consumption ( $\text{VO}_2$ max) Estimation using Direct and Indirect Method in Indian Population: A Pilot Study

KARAMPREET KOUR BUTTAR<sup>1</sup>, NEHA SABOO<sup>2</sup>, SUDHANSHU KACKER<sup>3</sup>



## ABSTRACT

**Introduction:** The maximal oxygen consumption ( $\text{VO}_2$  max) has been considered the single best indicator of the cardio respiratory fitness. Maximal oxygen consumption ( $\text{VO}_2$  max) is the maximum amount of oxygen a person can intake and utilise during intense exercise.

**Aim:** To estimate and compare  $\text{VO}_2$  max measured by using direct and indirect methods.

**Materials and Methods:** A prospective cross-sectional pilot study in which total of 100 apparently healthy students (male and female) were recruited from RUHS-College of Medical Sciences, Jaipur from January 2019 to August 2019.  $\text{VO}_2$  max of each participant was determined. Direct estimation of  $\text{VO}_2$  max comprised of sub-maximal exercise test on treadmill using gas analyser whereas  $\text{VO}_2$  max was indirectly predicted by standard protocol of Queen College step Test (QCT) with a gap of four days in between the tests. Collected data were entered in Microsoft-Excel and Paired t-test was used for statistical

analysis of data.

**Results:** The mean value of  $\text{VO}_2$  max (mL/kg/min) using direct method was  $44.66 \pm 9.25$  and that of using indirect method was  $48.00 \pm 8.02$ . There was statistically very significant difference between two methods of  $\text{VO}_2$  max estimation ( $p=0.0032$ ). Mean value of  $\text{VO}_2$  max for males was  $47.56 \pm 8.37$  mL/kg/min and for females it was  $37.62 \pm 7.40$  mL/kg/min, which was found statistically significant ( $p=0.0001$ ) higher in males than in females.

**Conclusion:** From the present investigation it may be concluded that the actual  $\text{VO}_2$  max is lower than the predicted  $\text{VO}_2$  max from the QCT which suggest that the prediction equation is not applicable to the studied population due to difference of ethnicity. With the help of estimated  $\text{VO}_2$  max we can find out physical fitness in individuals and creating awareness about physical activity and life style modification for primary prevention of cardiovascular, metabolic and mental disorders.

**Keywords:** Cardio-respiratory fitness, Queen college's step test, Volume of oxygen

## INTRODUCTION

Physical fitness refers to person's ability to work effectively, enjoy leisure time, be healthy, resist hypo-kinetic disease or condition and meet emergency situations. There are many factors which help to develop physical fitness, but regular physical activity is the key aspect to achieve optimal physical fitness [1]. In current scenario, the Cardio Respiratory Fitness (CRF) is regarded the most important health fitness parameter. The CRF or maximal aerobic power is the overall capacity of the cardiovascular and respiratory system and the ability to carry out prolonged strenuous exercise. The maximal oxygen consumption ( $\text{VO}_2$  max) attained during a graded maximal exercise till voluntary exhaustion has been considered the single best indicator of the cardio-respiratory fitness [2].

Maximal oxygen uptake ( $\text{VO}_2$  max) is one of the most commonly used parameter in exercise science for Cardio-respiratory fitness measurement. Firstly, Hill AV and Lupton H reported that there exists a limited rate of maximal oxygen transport from the environment to the mitochondria to support oxidative production of energy to do strenuous work [3]. Maximum oxygen uptake ( $\text{VO}_2$  max) is the maximum amount of oxygen can be taken-up and utilised by the person body during heavy exercise [4].  $\text{VO}_2$  maximum is considered as the gold standard to assess the cardio-respiratory endurance of the patient. People who possess a low  $\text{VO}_2$  max have an increased chance of premature death, as well as the development of numerous chronic diseases, whereas individuals with a high  $\text{VO}_2$  max have less chance of developing chronic diseases, all-cause mortality, and coronary artery disease [4]. The  $\text{VO}_2$  max can be estimated using maximal or sub-maximal tests, by direct or indirect methods. Direct measurement of  $\text{VO}_2$  max using Gas analyser and step and Field tests are used for indirect measurement of  $\text{VO}_2$  max [5].

The primary criteria for  $\text{VO}_2$  max is a plateau in  $\text{VO}_2$  despite increased exercise intensity [6]. In the case of a plateau in  $\text{VO}_2$  not being reached many secondary criteris including a rise in Respiratory Exchange Ratio (RER) above 1.15, blood lactate concentration above 8 mmol/L and increase in predicted heart rate according to age (i.e.,  $220 - \text{Age}$ ) [7].

In India, indirect method (QCT) is being used very frequently to estimate  $\text{VO}_2$  max due to its easy, safe, quick and feasible approach. As originally QCT was developed for Caucasian population, which is different from Indian population in terms of ethnicity. Few studies [8,9] done in India showed variation in value of  $\text{VO}_2$  max measured by using direct and indirect both methods. So the accuracy and applicability of QCT (indirect method) in Indian population is still to be defined. Hence, this study was designed to estimate and compare  $\text{VO}_2$  max measured by using direct and indirect methods.

## MATERIALS AND METHODS

This was a prospective cross-sectional pilot study, approved by the Institutional Ethical Committee of RUHS College of Medical Sciences, Jaipur. (Approval letter no RUHS-CMS/Ethics Comm/2018/148 dated-21/12/18) and conducted from January 2019 to August 2019.

**Inclusion criteria:** A total of 100 apparently healthy young medical students (Pilot-study) of both gender, aged between 18-25 years were recruited randomly for the study after obtaining their consent form.

**Exclusion criteria:** Individuals suffering from Hypertension, Diabetes, Cardiac, Respiratory and musculoskeletal disorders, Smokers, alcoholic and history of hospitalisation in the last 3

months were excluded.

Everything was explained to students regarding aim of the study and how the procedure will be performed. All the students were tested under similar laboratory conditions (27-29°C temperature and relative humidity ranging between 75%-80%). Subjects were also instructed not to have heavy meals/tea/coffee at least 2 hours and not have performed any exercise before the test. Detailed history was taken and clinical examination was done. The Anthropometric data which included age, height, weight, skin-fold thickness was measured as accordance to National Health and Nutrition Examination Survey (NHANES) [10] and Body Mass Index (BMI) and body fat percentage [11] were calculated.

**VO<sub>2</sub> max using direct method Analog-Digital (AD) instrument gas analyser (model-ML206):** Test protocol was explained to the subject and demonstrated the same. The subject was made to wear the mask which is in turn was connected to the equipment to measure the total amount of gases inhaled and exhaled during the test. Now we started the test procedure i.e., the treadmill graded exercise test protocol, in which subject was asked to walk for 3 minutes at level grade followed by jogging at self selected speed (b/w 4.3-7.5 mph) at level grade for 3 minutes and then with a constant speed, treadmill grade was increased by 2.5% every minute until the subject achieves fatigue and is unable to continue the exercise. Here, during the procedure, the equipment was connected to a monitor screen, which showed us various values e.g., Volume of Oxygen (VO<sub>2</sub>), Volume of Carbon-dioxide (VCO<sub>2</sub>), Resting Energy Expenditure (REE), Respiratory Exchange Ratio (RER), Metabolic Equivalent of Tasks (METs) etc., of every 10 seconds [12].

**VO<sub>2</sub> max using indirect method (QCT) [13]:** Test protocol was explained to the subject and demonstrated the same. The subject was then asked to rest in a supine posture for 30 min. The resting heart rate and the blood pressure were measured. The height of the step is to be kept at 16.25 inches and the stepping cadence is to be set at:

**Male:** 24 cycles/min **Female:** 22 cycles/min

Since there are 4 steps in each cycle, the metronome (electrical device that produce a regular repeated sound) is to be set at 88 ticks/min for females or 96 ticks/min for males. The stepping protocol was followed as: both feet on the ground, first foot on the step, step-up with the second foot on the step, both foot on the step, first foot back on the ground, and finally the second foot on the ground. The subject was asked to perform the test for 3 min. At the end of the test, the subject has to remain standing and the number of heart beats between the 5<sup>th</sup> and 20<sup>th</sup> second after the cessation of the test, is to be noted down. The pulse rate per minutes is calculated by multiplying it by a factor of 4. This is used to predict the VO<sub>2</sub> max by using the following formula [13].

**Male:** VO<sub>2</sub> max(mL/kg/min)=111.33-(0.42×pulse rate in beats/min)

**Female:** VO<sub>2</sub> max(mL/kg/min)=65.81-(0.1847×pulse rate in beats/min)

## STATISTICAL ANALYSIS

Collected data were entered in Microsoft-Excel (version-16) and Unpaired and Paired t-test was used to compare VO<sub>2</sub> max results measured by using direct and indirect methods.

## RESULTS

The study was conducted on 100 apparently healthy students (65 males and 35 females). Paired t-test was used to compare VO<sub>2</sub> max results measured by using direct and indirect methods. [Table/Fig-1] showed that Mean value of VO<sub>2</sub> max for males was 47.56±8.37 mL/kg/min and for females it was 37.62±7.40 mL/kg/min, which was found significantly higher in males than in females (p<0.0001).

	Males (n=65) (Mean±SD)	Females (n=35) (Mean±SD)	p-value	Inference
Age (Years)	20.06±2.09	20.09±2.36	0.9509	NS
Weight (Kg)	63.84±11.09	54.43±11.03	<0.0001	HS
Height (cm)	171.81±5.87	158.14±6.66	<0.0001	HS
BMI (Kg/m <sup>2</sup> )	21.64±3.54	21.60±4.00	0.9620	NS
Body Fat %	15.63±4.75	26.73±4.19	<0.0001	HS
GPAQ (METs)	1576±915	937.14±503.73	0.0002	VS
VO <sub>2</sub> max (mL/kg/min)	47.56±8.37	37.62±7.40	<0.0001	HS

**[Table/Fig-1]:** Age, BMI and Body Fat %, GPAQ and VO<sub>2</sub> max of male and female subjects.

p-value: Probability-value; NS: Non significant; HS: Highly significant; VS: Very significant; BMI: Body mass index; Unpaired t-test was used to compare variables between male and female; VO<sub>2</sub>: Volume of oxygen; SD: Standard deviation; METs: Metabolic equivalent of tasks

	VO <sub>2</sub> max (mL/kg/min) using direct method	VO <sub>2</sub> max (mL/kg/min) using Indirect method	p-value	Inference
	Mean±SD	Mean±SD		
Males	47.56±8.37	50.86±7.39	0.0070	VS
Females	37.62±7.40	40.83±4.15	0.0304	S
Overall	44.66±9.25	48.00±8.02	0.0032	VS

**[Table/Fig-2]:** Comparison of VO<sub>2</sub> max using Direct and indirect method in male and female subjects.

p-value: Probability-value; S: Significant; VS: very significant; Paired t test was used; SD: Standard deviation

[Table/Fig-2] showed that the mean value of VO<sub>2</sub> max (mL/kg/min) using direct method was 44.66±9.25 and that of using indirect method was 48.00±8.02. There was statistically very significant difference between two methods of VO<sub>2</sub> max estimation (p=0.0032).

## DISCUSSION

VO<sub>2</sub> max measurement using gas analyser has been used as the gold standard method for assessing cardio-respiratory fitness. Queen college step test was originally formulated for Caucasian population but is being widely used for measuring VO<sub>2</sub> max even in Indian population, which differs from the ethnicity of Caucasian population. The present study measured Cardio-respiratory fitness by estimating VO<sub>2</sub> max and compared the result of VO<sub>2</sub> max obtained using direct (Gas Analyser) and indirect method (QCT), were found statistically very significant (p=0.0032). The actual VO<sub>2</sub> max is lower than the predicted VO<sub>2</sub> max from the QCT which suggest that the prediction equation is not found to be applicable to the studied population. In earlier studies, Chattarji S et al., reported that original predictive equation of QCT cannot be applied on Indian population due to difference of VO<sub>2</sub> max value using direct and indirect method [8,9].

In this present study, the mean value of VO<sub>2</sub> max for males was 47.56±8.37 mL/kg/min and for females was 37.62±7.40 mL/kg/min, which was significantly high in males (p<0.0001). Findings of this study are in agreement with other studies [14,15]. Modala S et al., in their study found that the mean value of VO<sub>2</sub> max was 51.76±3.8 in males and 44.07±4.2 in females [15]. Bandyopadhyay A and Bandyopadhyay P reported that males have superiority than their female counterpart [16]. The males are higher to females in cardio-respiratory fitness because, lower fat percentage and others factors mainly linked to the cardiac size and oxygen-carrying capacity (i.e., left ventricular inner diastolic diameter, maximal heart rate (HR max) and maximal stroke volume) [17], The reason for reduced VO<sub>2</sub> max in the female subjects of the present study, than the male subjects could be because of the significantly decreased physical activity level and significant higher level of body fat percentage.

On comparison of the VO<sub>2</sub> max value in the present study with the standard VO<sub>2</sub> max classification, this study subjects fitted in the category of good on cardio-respiratory fitness (VO<sub>2</sub> max) scale [18]. Mean body fat percentage of males was 15.63±4.75 and for females

it was 26.73±4.19, which was found statistically significantly higher in females than in males (p<0.001). These results are consistent with the findings of several studies in the literature [19,20]. Sharma M et al., reported a high negative correlation between VO<sub>2</sub> max and body fat percent in healthy males [19]. Mondal H and Mishra SP, also reported that increased body fat percentage is associated with decreased level of VO<sub>2</sub> max in adults [20]. The assessment of cardio-respiratory fitness is valuable while educating individuals about their overall fitness status, developing exercise programs and quantifying cardio-vascular risk.

### Limitation(s)

This study is not applicable to all age groups. So, further studies can be done in larger sample size of all age groups and new regression equation should be developed for studied population.

### CONCLUSION(S)

The present study concludes that Direct method of VO<sub>2</sub> max using gas analyser provides more valid and accurate result than Indirect method (QCT). This study suggests that QCT in its original form cannot be applied in this study population. QCT is quickest, easiest and safest as well as feasible way to measure until a new modified equation is developed to measure VO<sub>2</sub> max for this studied population.

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#### PARTICULARS OF CONTRIBUTORS:

1. Student, Department of Physiology, RUHS College of Medical Sciences, Jaipur, Rajasthan, India.
2. Assistant Professor, Department of Physiology, RUHS College of Medical Sciences, Jaipur, Rajasthan, India.
3. Professor, Department of Physiology, RUHS College of Medical Sciences, Jaipur, Rajasthan, India.

#### NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Neha Saboo,  
RUHS College of Medical Sciences, Jaipur, Rajasthan, India.  
E-mail: nehasaboo8@gmail.com

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