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Original Article

Physiology Section

Normative Data of Maximal Oxygen Consumption (VO_2 Max) among Healthy Young Adults: A Cross-sectional Study

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ABSTRACT

Introduction: Maximal oxygen uptake (VO_2 max) is the maximum quantity of oxygen a person can consume, and it remains constant over time despite increased exertion. The amount of oxygen consumed by the working muscles is measured by maximal oxygen consumption. The maximal oxygen uptake can be measured using maximal or submaximal tests, by gas analyser or field methods. The estimated VO_2 max can be used to study people's fitness and raise awareness about physical activity and lifestyle changes.

Aim: To determine the VO_2 max values using a direct method and provide normative data of VO_2 max for healthy young adults in the age group of 18-25 years in both sexes.

Materials and Methods: This cross-sectional study was approved by the Institutional Ethical Committee of RUHS College of Medical Sciences, Jaipur, Rajasthan, India. A total of 419 healthy young adults (male and female students) were recruited from RUHS-College of Medical Sciences and MNIT College, Jaipur, Rajasthan, India from January 2019 to March 2020. Anthropometric data included age, height, weight according to the National Health and Nutrition Examination Survey (NHANES) and followed by measurement of VO_2 max using a gas analyser of AD-Instrument (model-ML206). Collected data was entered in Microsoft excel. Paired t-test was used to compare mean and Standard Deviation (SD) of variables between male and female participants. The p-value of <0.05 was considered as significant.

Results: The study was conducted on 419 apparently healthy college students (275 male and 144 female). The mean VO_2 max value for males was 45.30±7.35 mL/kg/min and for females it was 35.71±5.29 mL/kg/min, which was found to be significantly higher in males than in females. The mean VO_2 max among the largest proportion of the males (27.63%) falls in the 'Good' category of cardiorespiratory fitness scale and the largest proportion of the females (32.63%) falls in the 'Fair' category of cardiorespiratory fitness scale.

Conclusion: The value of VO_2 max was lower in the Indian population than in the western population, when value obtained from this study was compared with the standard normative value of cardiorespiratory fitness. Therefore, the values obtained in this study could serve as a normative for the Indian population.

Keywords: Cardiorespiratory fitness scale, Direct method, Gas analyser, Maximum oxygen consumption, Normative value

INTRODUCTION

Cardiorespiratory fitness, also called cardiovascular fitness or high aerobic strength, is the total capacity of the heart, blood, and respiratory systems and the ability to perform prolonged strenuous physical activity. Maximal oxygen uptake (VO_2 max) achieved during maximal graded exercise to voluntary exhaustion has long been considered by the World Health Organisation (WHO) to be the single best measure of cardiorespiratory fitness [1]. Maximal oxygen uptake (VO_2 max) is the maximum amount of oxygen a person can consume, and it remains constant over time despite increased exertion. The amount of oxygen consumed by working muscles is measured by maximal oxygen consumption. It is expressed in L/min in absolute value or in mL/kg/min in relative VO_2 max [2]. Maximal oxygen uptake (VO_2 max) is one of the most widely available measurements in exercise physiology. VO_2 max has been used in various ways in clinical science as a measure of physical performance [3]. It is a marker of physical fitness and cardiovascular disease in the population [4]. The use of VO_2 max is widespread, ranging from elite athletes to people with multiple medical conditions [5].

Hill AV suggested that there is a limited rate of transport of large amounts of oxygen from the environment to the mitochondria to support oxidative production of Adenosine triphosphate (ATP) to perform physical activity [6]. Maximal oxygen uptake is a marker of individual's fitness and many heart disease in the population. A person's max is the gold standard for assessing their cardiorespiratory endurance [7].

According to Shephard RJ, the primary endpoint for achieving VO_2 max is a VO_2 plateau. Several secondary criteria exist in the event that a VO_2 plateau is not reached, including an increase in the Respiratory Exchange Rate (RER) greater than 1.15, a blood lactate concentration greater than 8 m mol/L and an increase in heart rate to the age-predicted maximum [8]. A person's cardiorespiratory fitness can be measured using VO_2 max estimation by direct or indirect methods [9]. Cardiorespiratory fitness is categorised as Very Poor, Poor, Fair, Good, Excellent, and Superior for both genders based on Western population VO_2 max values [10].

Direct method: (laboratory method) Measures an individual's expired gases for analysis of pulmonary ventilation, inspiratory O_2, and expired CO_2. Direct measures accurately determine a person's higher oxygen consumption by breathing through air analysis.

Indirect methods: These include field tests, measuring a person's aerobic strength based on heart rate; distance travelled, or test duration when a specific procedure is used.

Previous research has used both direct and indirect approaches to generate normative values for VO_2 max in the Caucasian population, and standard ranges that predict whether an individual's cardiorespiratory fitness falls into the upper or lower have been calculated accordingly [11,12]. However, only a few studies have been performed using the direct technique of analysis of maximal oxygen consumption in the Indian population, and there is no standard or range by which VO_2 max can be compared for this population [13,14].

John N et al., explained that the Indian population differs from the Western population in many ways, including body stature, lifestyle, diet, nutrition, and physical activity levels, all of which can directly

or indirectly influence the maximal oxygen consumption [13]. Ethnic background has an effect on VO_2 max, and Indians differed significantly from whites in terms of physical appearance, nutrition, exercise, environment, and socio-economic characteristics [15]. However, despite its usefulness, there is a lack of data, especially for the healthy Indian population using the direct method. To compare previous studies, there is no such type of study available to estimate VO_2 max in the Indian population using the direct method in both sexes. Therefore, it is important to have another set of values to compare with the VO_2 max for the Indian population. Hence, the current study aims to determine VO_2 max values using a straightforward method and to provide normative data for VO_2 max for healthy adults in the age group 18-25 years for both sexes.

MATERIALS AND METHODS

This cross-sectional study was carried out in the Research Laboratory of the Department of Physiology at RUHS College of Medical Sciences, Jaipur, Rajasthan, India after obtaining approval from the Institutional Ethics Committee (IEC) (letter of approval no. RUHS-CMS/Ethics Comm/2018/148 of 21/12/18), the study was conducted from January 2019 to March 2020.

Inclusion criteria: Only active healthy adults between the 18-25 years age group of either sex were included in present study.

Exclusion criteria: Individuals with hypertension, diabetes, heart, respiratory and musculoskeletal disorders and had a history of hospitalisation within the past three months, smokers and alcoholics were excluded from the study. Students who regularly practice physical exercise or Yoga were also excluded from the study.

Sample size calculation: The sample size (381+38=419) was calculated using the standard formula $n=Z^2pq/d^2$ with a confidence level of 95%, a margin of error of 5% and a non response of 10% based on the prevalence of 45.6% of physically active individuals in the Indian Council of Medical Research (ICMR)-India Diabetes (INDIAB) study (2014) [16].

Study Procedure

A total of 419 young healthy medical students of both sexes, aged 18-25 years, were recruited with the help of a computerised random table generator for the study. Preliminary information on the purpose of the study, the test procedure, the test method, instructions on how to perform the test was provided via the Participant Information Sheet (PIS), then the subjects were recruited for the study of the test after signing the consent form. Physical activity was assessed using the global physical activity questionnaire [17]. Subjects were considered physically active when they achieved Metabolic Equivalent of Tasks (MET) tasks of ≥600 per week. Based on the questionnaire, physically inactive students (METs <600) were excluded from the study. The subject did not perform any form of exercise prior to the test.

Subjects were examined under similar laboratory conditions (temperature 27-29ºC and relative humidity between 75% and 80%). They were also asked to avoid heavy meals/tea/coffee and any type of exercise atleast two hours before the test. A detailed medical history was collected and a clinical examination was performed prior to starting the test procedure. Anthropometric data, which included age, height, weight, were measured in accordance with the National Health and Nutrition Examination Survey (NHANES) and the Body Mass Index (BMI) was (18.5 -24.75 kg/m^2). Each subject's BMI was calculated as weight in kg divided by height in square metres [18]. VO_2 max was measured using a direct method with the help of the gas analyser of the instrument AD (model-ML206): subjects were asked to come in the morning or 2-3 hours after the last meal. The classified exercise test protocol was first explained and demonstrated to the subjects before proceeding further with it. The subjects were made to wear a mask connected to the gas analyser that measures the total amount of gas inhaled and exhaled during the test. The treadmill graduated stress test protocol was followed in which subjects were asked to walk for three minutes at the horizontal level followed by jogging at the selected speed (b/w 4.3-7.5 mph) at the level of incline for three minutes and then at a constant speed, The grade of the treadmill was increased by 2.5% every minute until the subject becomes tired and unable to continue exercising. The equipment is connected to a monitor screen, which shows the various values, eg. Oxygen volume (VO_2), Carbon dioxide volume (VCO_2), Respiratory Exchange Ratio (RER), MET etc. every 10 seconds [19]. Cardiorespiratory fitness is classified into very poor, poor, fair, good, excellent, superior categories in both sexes based on the VO_2 max values of the Western population [20].

STATISTICAL ANALYSIS

The Kolmogorov-Smirnov test was performed to test the normality of the outcome variables. All data were presented as mean±SD. An independent t-test was used to compare the mean differences and SD of the variables between male and female participants. The p-value <0.05 was considered significant.

RESULTS

The study was conducted on 419 healthy students (275 males and 144 females). [Table/Fig-1] shows the mean age of male was 20.34±2.02 years and female was 20.22±2.02 years (p=0.56). The mean BMI (Kg/m^2) of males was 21.94±2.99 and females was 21.21±3.02 kg/m^2 (p=0.02), and the mean body fat % in male was 14.51±4.74% and for women it was 22.82±6.27%. The mean value of VO_2 max for males was 45.30±7.35 mL/kg/min and for female it was 35.71±5.29 mL/kg/min, which was found significantly higher in males than in females (p<0.001).

Parameters	Males (n=275) (Mean±SD)	Females (n=144) (Mean±SD)	t	Sig (2-tailed)
Age (years)	20.34±2.02	20.22±2.02	0.57	<0.001
Weight (Kg)	65.45±9.68	54.28±8.54	11.65	<0.001
Height (cm)	172.70±5.61	159.99±5.50	22.16	<0.001
BMI (Kg/m^2)	21.94±2.99	21.21±3.02	2.33	0.02
Body fat %	14.51±4.74	22.82±6.27	15.19	<0.001
Physical activity (METs)	1433.82±721.98	909.58±431.74	7.99	<0.001
VO_2 max (mL/kg/min)	45.30±7.35	35.71±5.29	13.87	<0.001

[Table/Fig-1]: Descriptive statistics of respondents (Male and Female).

[Table/Fig-2] shows mean value of VO_2 max for male and female and its range. [Table/Fig-3] shows comparison of mean±SD VO_2 max among the majority of the male was found (27.63%) in the good category, 2.54% proportion fell in the very poor category and 20.72% fell in the superior category of cardiorespiratory fitness normative value.

VO_2 max	Mean±SD	Range	
		Minimum	Maximum
VO_2 max in male (mL/kg/min)	45.30±7.35	31.19	52.43
VO_2 max in female (mL/kg/min)	35.71±5.29	22.79	41.21

[Table/Fig-2]: Normative value of VO_2 maxes in respondents (Male and Female).

Category	Range	Mean±SD	Distribution (n)	Percent (%)
Very poor	<33.0	32.09±1.10	7	2.54
Poor	33.0-36.4	34.75±3.50	26	9.45
Fair	36.5-42.4	39.50±6.00	45	16.36
Good	42.5-46.4	44.50±4.00	76	27.63
Excellent	46.5-52.4	49.45±5.90	64	23.27
Superior	>52.4	55.96±3.90	57	20.72

[Table/Fig-3]: Distribution of male subjects in different cardiorespiratory fitness categories.

[Table/Fig-4] shows comparison of mean VO_2 max among the majority of the females (32.63%) found in the fair category, the lowest portion (3.47%) fell in the very poor category and 15.97% were found in the superior category of cardiorespiratory fitness normative value.

Category	Range	Mean±SD	Distribution (n)	Percent
Very poor	<23.60	23.19±0.45	5	3.47
Poor	23.60-28.9	26.30±5.40	9	6.25
Fair	29.0-32.9	31.00±4.00	47	32.63
Good	33.0-36.9	35.00±4.00	23	15.97
Excellent	37.0-41.0	39.00±4.00	37	25.69
Superior	>41.0	42.11±1.82	23	15.97

[Table/Fig-4]: Distribution of female subjects in different cardiorespiratory fitness categories.

DISCUSSION

The assessment of cardiorespiratory fitness is invaluable in educating individuals about their overall fitness status, developing exercise programs, and quantifying cardiovascular risk.

According to [Table/Fig-1], the average age of the male was 20.34±2.02 years and the female 20.22±2.02 years (p=0.56). There was no statistically significant difference in age in two groups. In this study, mean VO_2 max was 45.30±7.35 mL/kg/min for males and 35.71±5.29 mL/kg/min for females, which was statistically significantly higher in males (p<0.001). The results of present study was consistent with other studies that have examined VO_2 max in male subjects and were significantly higher compared to female participants [21]. Comparing the VO_2 max values of present study with previously published values in the western population, it is noticeable that the VO_2 max values were higher in the western population study. In this case, the VO_2 max for males was 48.6±9.6 mL/kg/min and for females 40.3±7.1 mL/kg/min [22]. A study conducted by McArdle WD et al., this difference was attributed to differences in body composition and blood haemoglobin concentration. An unfit young adult woman has 25% body fat, while the average for men is 15% [23]. Therefore, male generate more overall aerobic energy simply because they have greater muscle mass (and less fat than females), which in turn leads to increased oxygen uptake and utilisation. Bandyopadhyay A and Bandyopadhyay P reported that males are superior to their female counterparts [24]. Men outperform women in cardiorespiratory fitness due to lower body fat percentage and other factors related primarily to heart size and oxygen carrying capacity (maximum heart rate (HRmax) and maximum stroke volume) [25].

According to [Table/Fig-2], the mean VO_2 max in males was 45.30±7.35 mL/kg/min with a minimum of 31.19 mL/kg/min and a maximum of 52.43 mL/kg/min. The mean VO_2 max in females was 35.71±5.29 mL/kg/min with a minimum value of 22.79 mL/kg/min and a maximum value of 41.21 mL/kg/min. When comparing VO_2 max to the standard VO_2 max classification, subjects in this study are classified as good on the cardiorespiratory fitness (VO_2 max) scale [20]. Similar results were obtained in the study by Nitin YM et al., who observed the VO_2 max using the direct method in 20 male young adults. They observed that VO_2 max ranged from 22.9 mL/kg/min to 47.8 mL/kg/min and 60% of the subjects fell in the good category [10]. The mean VO_2 max obtained from this study was lower compared to those obtained in the Caucasian population [20]. Similar results were found in another study conducted by John N et al., that examined the difference in maximal oxygen consumption in 101 Indian adults and developed a predictive equation. VO_2 max was shown to be significantly lower in the Indian population than in the Western population. It revealed that VO_2 max was influenced by ethnicity and that Indians differed greatly from whites in terms of body structure, diet, physical activity, environment and socio-economic factors [13].

[Table/Fig-3,4] show the current VO_2 max value compared to the standard VO_2 max categorisation. There is a different fitness scale for men and women, and when subjects were placed into the fitness levels, the majority of men (27.63 percent) fell into the VO_2 max category good but the majority of women had fair VO_2 max. Furthermore, 20.72% of the male population had an outstanding maximal oxygen uptake compared to 15.97% of the female population. VO_2 max (most subjects belong to cardiorespiratory fitness group fair or good) in current subjects could be due to decreased physical activity and harmful lifestyle patterns developed over years of education, which could influence the behaviour and health of adults condition. These findings are in line with those of several other investigations published in the literature [21,26]. This finding was consistent with the findings of a previous study by Varghese RS et al., which indicated that the majority of men (24.3%) had a VO_2 max above average, while the majority of women (48.2%) had a VO_2 max below average [26].

Directly measured VO_2 max is one of the basic index measures to assess cardiorespiratory fitness, reflecting the state of the circulatory and respiratory systems. Lack of cardiorespiratory fitness may play a role in the global increase in the prevalence of degenerative cardiovascular diseases. VO_2 max represents a fundamental measure in exercise physiology and serves as a standard for estimates of aerobic capacity.

Limitation(s)

This study included only healthy young adult students in the age group 18-25 years. The sample size was small and the study was not applicable to all age groups. Therefore, more studies can be carried out in a larger sample size with different age groups.

CONCLUSION(S)

The present study concluded that the VO_2 max value was lower in the Indian population than in the Western population, when the value obtained in this study was compared with the standard normative value of cardiorespiratory fitness. The maximal oxygen consumption (VO_2 max) value of this study could be used as a standard for cardiorespiratory fitness scale for healthy young adults in Indian. People's fitness can be measured using estimated VO_2 max and awareness can be raised about the relevance of physical activity and lifestyle adjustment in the primary prevention of cardiovascular, metabolic and mental diseases.

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