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VO_2 Max Normative Values Using Queen's College Step Test in Healthy Urban Indian Individuals of Age Group 20-50 Years

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Abstract: ***Background: Physical Fitness has been defined as a set of attributes that people have or achieve that relates to physical activity and can be either health or skill related. This study aims at determining one of the crucial health related factors- Cardiovascular endurance measured by standard parameter- maximal uptake of oxygen (VO_2max) and its association with gender in the Indian urban population. Methods: 501 individuals consisting of both males and females from 20 to 50 years of age were subjected to the Queens College Step Test (submaximal exercise test). The heart rate obtained immediately after the test was then substituted in the formula, based on gender, to predict the VO_2max indirectly. Results: Normative VO_2 values obtained for 501 individuals were in the range of 38.41+/-6.95ml/kg/min. VO_2max was also found to have an association with age and gender ($p<0.05$). Conclusion: Normative range of VO2 max was established within the age group. Mean VO_2max was seen to be best in the youngest age group of the study and superior in males when compared to females.***

Keywords: VO_2 max, Queen's College Step Test, Cardio respiratory endurance, Sub maximal exercise test

1. Introduction

Physical fitness has been defined as a set of attributes or characteristics that people have or achieve, that relates to the ability to perform physical activity. These characteristics are usually segregated as Health or Skill related components. The health related components consist of cardiovascular endurance, muscular strength and endurance, flexibility and body composition while agility, coordination, balance, power, reaction time and speed belongs to the skill related part of fitness[1]. Previous studies have established cardiovascular endurance to be one of the best predictors in assessing mortality and morbidity rate of individuals suffering from coronary artery diseases (CAD). It is believed that the more fit or active the individual, the chances of him developing coronary artery diseases and associated co morbid factors are less in comparison to his sedentary counterpart[2]. Therefore, essentially cardio respiratory fitness level is a measure of the strength of an individual's aerobic system.

It includes 2 components: The ability of the body to transport oxygen to the muscles during prolonged exercise and the ability of the muscles to absorb and use this oxygen while exercising. The first component involves oxygen being absorbed into the pulmonary blood capillaries, which is then transported via the pulmonary vein to the left side of the heart and pumped out to the muscles and tissues to carry out daily vital functions. At the same time, there is carbon dioxide washout, which is a waste product of cellular respiration. The second aspect is a measure of the ability of the vasculature and the lungs to work together in order to transport oxygen to the muscles through the oxygen delivery transport system[3].Since, cardio respiratory fitness or endurance is quantified as a measure of maximal uptake and use of oxygen at cellular level during prolonged activity, it is only fair that this uptake of oxygen is measured by various parameters, one of which is maximal consumption of oxygen which refers to the highest rate at which oxygen can be taken up and consumed by the body during intense exercise [4].VO_2 max is also accepted as the criterion measure of cardio respiratory endurance[5] and provides knowledge of an individual's functional ability. It is given by the product of maximum cardiac output and arterial-venous oxygen difference expressed in ml O_2/ litre blood[6].Since VO_2max is one the measures of cardio respiratory fitness, any factor that affects the Cardiac Output and difference in arterial and venous oxygenation affects it. **Mc Ardle et al**[6]established that the relationship between cardiac output and maximal oxygen consumption is a direct one, that is increase in cardiac output will directly improve a person's capacity to circulate oxygen and thereby increase his maximal oxygen consumption.

Over the years, many techniques have been used to determine VO_2max which involves both direct and indirect ones. Initially, measuring VO_2 max required sophisticated equipment, usually a treadmill or cycle ergometer with an open circuit spirometry, where the subject was asked to breathe through a low-resistance valve with his nose occluded. During this, the pulmonary ventilation and expired fractions of oxygen and carbon dioxide were measured. In current times, due to problems associated with increased cost of equipment, space and personnel, indirect measurements have become more popular. A variety of sub maximal and maximal exercise tests can be used to determine VO_2 max. These tests have been validated by examining: a) The correlation between directly measured VO_2 max and VO_2 max estimated from physiological responses to sub maximal exercises or b)The correlation

between directly measured VO_2max and test performance using a standard graded exercise protocol[1].

The decision to use a sub maximal or maximal exercise test depends upon the availability of the appropriate equipment and personnel. Maximal exercise testing is not always feasible, as it may require the individual to exercise to the point of complete exhaustion. It may also require medical supervision and emergency equipments. Hence sub maximal tests are commonly relied on to assess cardio respiratory fitness and thereby provide information about an individual's sub maximal exercise response over time in a controlled environment and to accordingly modify his exercise prescription[1].There are various modes used for exercise testing which includes field tests, treadmill tests, cycle ergometer tests and step tests. Furthermore, sub maximal tests are classified as predictive or performance tests. Predictive sub maximal tests may also be further divided into treadmill and field tests. 'Queens College Step test[6], [7] is a field test requiring a step of 16.25 inches in height. Being inexpensive and requiring minimal use of equipment, it can be conducted in a certain population to determine the fitness index, VO_2max, when sophisticated equipments are not available.

McArdle et al[7]in 1972, determined the reliability and validity for a 3 minute step test i.e Queen's College Step test for evaluating VO_2max in a large number of college women. A significant high correlation (r=-0.75) was obtained between the VO_2 max(ml/kg/min) and the 5^{th}-20^{th}second recovery heart rate after the 3 minute step test. Another study conducted by **S. Chatterjee et al**[8] in 2004 aimed at studying the suitability of Queens College Step test to predict maximal oxygen uptake in 30 male sedentary students. It proved that the step test could be confidently used in place of complicated and exhaustive direct procedure for VO_2max prediction. In 2009, **J.P Verma et al**[9] studied a simple technique of determining VO_2max from a three minute step test that is Queens College Step test as an alternative to direct method, using the heart rate after performing the step test. A significant negative correlation was established(r=-0.7) between VO_2max and pulse rate obtained after performing the Queens College Step test. In 2013, **Zar Abdossaich et al**[10] revealed a significant statistical correlation (r=0.68, p<0.001) between the direct (20m Shuttle Run Test) and indirect (Queens College Step Test) in 30 randomly selected healthy sedentary male students belonging to the same socioeconomic background from the University of Shiraz, concluding that the Queens College Step Test could be applied to produce a good estimation of VO_2 max in a large population where well equipped laboratories were unavailable.

Previous studies have established normative values for VO_2max in Caucasian population using direct and indirect methods, and accordingly standard ranges estimating whether the individual's aerobic capacity lies in the superior or inferior category have been determined. From this the therapist acquires an idea about the level or intensity of exercise an individual can be trained with. However, little research has been done on studying the trend of maximal consumption of oxygen in Indian population and there is no benchmark or range with which the VO_2max of this population can be compared. It should also be considered that Indian population differs from the Caucasian population in many ways like in their body stature, lifestyle, diet and nutrition, levels of physical activity which could directly or indirectly affect this parameter, as shown by **Neethu John et al**[11] in 2011. She stated that VO_2max was affected by the ethnic background and that Indians differed highly from the white population in their body stature, nutrition, physical activity, environment and socioeconomic factors. Thus, it is of grave importance that there is a different set of values on the basis of which VO_2max of Indian urban people can be compared. Therefore this study was undertaken to determine the normative VO_2 max values in urban Indian people in the age group of 30 -50 years.

2. Methodology

The study was approved by the institutional ethics committee & carried out as a cross sectional observational study in different areas of the community like religious centres, housing societies, offices and colleges over a period of 12 months, after obtaining consent from the respective individual leaders of these community areas. After screening, 501 normal healthy individuals (males and females) from urban areas were divided into 3 age categories (20-29, 30-39 &40-49 years) consisting of n=165, n=169 & n=167 respectively, to perform the Queens College Step Test protocol in order to determine their respective VO_2max. Subjects with any cardiac, respiratory, metabolic, gastrointestinal, genitourinary disorders, musculoskeletal or neurological conditions affecting the lower limbs, causing limitation in lower limb activities and undergoing any sort of treatment at that time were excluded.

After obtaining a written consent, the subject's demographic details i.e age, gender, height and weight for BMI estimation and Waist to Hip ratio were recorded. The individuals were then asked to perform the Queen's College Step Test by simply stepping up and down alternately on a step bench of 16.25 inches at 24 steps/min (males) and 22 steps/min (females) respectively for 3 minutes after which their radial pulse was recorded from the 5^{th} to the 20^{th} second in the sitting position. Prior to this, each subject was seated for 5 minutes during which their pulse rate (PR) was recorded for a period of 1 minute. The pulse rate obtained after the test was then substituted in the formula: 111.33- (0.42* PR per minute) for males and 65.81 - (0.1847* PR per minute) for females[12], to yield the VO_2max values and be categorized according to the norms.

The data collected was analysed using the IBM-SPSS Statistics software version 19. Estimation of normal values of VO_2max of individuals were done using descriptive statistics, that is measures of central tendency. Chi square test was used to associate the gender with VO_2max & Kruskal Wallis test was used to compare the VO_2max obtained among the three age groups as the data did not pass the normality test. Mann Whitney U test was used to compare the VO_2max obtained between the genders, as the data was not normally distributed and for the purpose of this study, a 'p' value of <0.05 was considered statistically significant.

3. Results

Table 1: Distribution of males, females, their height, weight and BMI in each age g roup

Gender	Age in years		
	20-29	30-39	40-49
Male	84	100	120
Female	81	69	47
Mean height(m)+/- sd	1.64±0.09	1.66±0.08	1.689±0.06
Mean weight (kg) +/-sd	66.12± 11.63	67.67± 9.67	69.59±7.69
Mean BMI (kg/m^2)+/- sd	23.87±2.76	24.35±2.33	24.36±2.10

Out of the 501 subjects tested, 304 that is 60.67% were males and the remaining 197 that is 39.32%were female

Table 2: Normative values of VO2 max

	Mean	±SD	Min value	Max value
VO2max	38.41	6.96	21.48	60.93

Table 3: Comparison of VO_2max among the three age groups

Age Groups	N	Mean±SD	Rank	P value
1	165	42.93±7.30	339.75	<0.05 (sig)
2	169	36.92±5.14	220.74	
3	167	35.44±5.90	193.93	

Table 4: Distribution of males and females in different VO_2max categories

Gender	VO2 max category						
	EXC	Good	AB AVG	AVG	BEL AVG	Poor	V Poor
Count	5	69	74	70	54	27	5
% male	1.6%	22.7%	24.3%	23.%	17.8%	8.9%	1.6%
count	0	1	21	70	95	9	1
% Female	0.0%	0.5%	10.7%	35.5%	48.2%	4.6%	0.5%

For applying Chi square test columns 1&2 were clubbed.

Table 5: Association of gender with VO_2max category

	value	Df	P value
Chi square	105.382	4	<0.05(sig)

Table 6: Mean VO_2max in both genders

Gender	N	Mean ±SD	Rank	Z value	P value
Male	304	41.09 ±7.24	310.05	-11.351	<0.05
Female	197	34.26 ±3.73	159.88		

4. Discussion

To summarize, the normative VO2max value of 501 individuals having mean age of 33.89+/-8.53 years with mean BMI of 24.19+/-2.42 kg/m sq was found to be 38.41+/-6.95ml/kg/min. Comparison of mean VO2max among the three age groups revealed that the lowest age group (20-29 years) had the best VO2max followed by the second age group (30-39 years) and the third age group (40-49 years) which was statistically significant($p<0.05$). Larger proportion of the males (24.3%) fell in the above average category of VO_2max whereas larger proportion of the females (48.2%) had below average VO_2max. Also 1.6% of male population had excellent maximal uptake of oxygen when compared to none that had same in the female population. A significant association ($x^2=105.382$, $p<0.05$) was established between gender and VO_2max, concluding that gender of the individual would have an effect on the maximal consumption of oxygen. Comparison of mean VO_2max between males and females revealed that males had a higher maximal uptake of oxygen as compared to females which was considered statistically significant ($p<0.05$).

VO_2max represents the maximal consumption of oxygen of an individual, when he is subjected to strenuous form of exercise. Therefore, it is the greatest amount of oxygen a person can use to produce ATP aerobically on a per minute basis. It determines the aerobic capacity and furthermore, the attainment of VO_2max requires integration of the ventilatory, cardiovascular and neuromuscular system. In essence, it represents a fundamental measure in exercise physiology and serves as a standard to compare performance estimates of aerobic capacity and endurance fitness [6] . Directly estimated VO_2 max is considered as one of the standard index measures for assessing cardiorespiratory fitness[12] which eventually reflects the status of the cardiovascular and respiratory system. Lack of cardiorespiratory fitness may well contribute to the increasing prevalence of degenerative cardiovascular disease throughout the world.

The present study was conducted on 501 individuals ranging from 20 to 50 years of age .The VO_2max values of these 501 subjects were then obtained using specific equations which were different for males and females as mentioned in the methodology. The mean value of VO_2max was 38.41ml/kg/min ± 6.96ml/kg/min with minimum value of 21.48 ml/kg/min and maximum value of 60.93ml/kg/min. The mean VO_2max obtained from this study was lower, when compared to those obtained in the Caucasian population.

Neethu John et al[11] in 2011 studied the difference in maximal consumption of oxygen in 101 Indian adults and developed a prediction equation for the same, as the presently used equations were derived from studies of western population. They demonstrated that VO_2max in the Asian Indian population was significantly lower than white population. They stated that VO_2max was affected by ethnic background and that, the Indians differed highly from the white population in their body stature, nutrition, physical activity, environment and socioeconomic factors. All the above mentioned reasons could have contributed to similar results obtained in the current study. Another study by **CP Hardy et al**[13] in 1985, also determined that anglosaxon male students had higher absolute and relative maximal oxygen consumption when compared to expatriated Indian male college students (57ml/kg/min and 50.5ml/kg/min; $p<0.01$) .The lower value of VO_2max was attributed to the decreased oxygen consumption per unit of lean body mass in the Indian group. The wide range of VO_2max values that was obtained from 501 individuals in the present study can be attributed to the disparity in the age and other factors like gender, physical activity, lifestyle, body composition etc [6].

On comparing VO_2max among different age groups, it was clearly observed that there was a significant difference ($x^2=95.532$,$p<0.05$). The mean VO_2max of the three age groups was 42.93 ± 7.30 ml/kg/min (20-29years), 36.92 ± 5.14ml/kg/min (30-39years) and 35.44 ± 5.9ml/kg/min (40-49years). This indicates that the younger age group had higher values and as age advanced, there was a gradual

decrease in the oxygen uptake. Age related changes of the cardiorespiratory system can explain the results mentioned above, as this indirectly affects the cardiorespiratory fitness and causes reduction of VO_2max.

Lastly on comparing VO_2max between the two genders, it was seen that a statistically significant difference existed ($Z=-11.351$, $p<0.05$). The mean VO_2max values for men and women were 41.09ml/kg/min and 34.26ml/kg/min respectively. This suggested that maximal oxygen uptake in males was far superior to that of the females.

According to **Mc Ardle et al**[6], VO_2 max for women typically averages 15- 30% below the values for men. This difference has been attributed to the disparities in body composition and blood hemoglobin concentration. An untrained young adult women possesses 25% body fat whereas the corresponding values for men averages 15%. Therefore the males generate more total aerobic energy simply because they possess large muscle mass (and less fat than females) which again leads to increased oxygen uptake and utilization.

5. Conclusion

Normative VO2max value of 501 individuals having mean age of 33.89+/-8.53 years with mean BMI of 24.19+/-2.42 kg/m sq was found to be 38.41+/-6.95ml/kg/min Lowest age group (20-29 years) had the best VO2max followed by the second age group (30-39 years) and the third age group(40-49 years). Significant association was established between gender and VO2max, concluding that gender of the individual would have an effect on maximal consumption of oxygen. Males had a higher maximal uptake of oxygen as compared to females which was considered statistically significant .

6. Clinical Application

The values obtained in this study could serve as a benchmark for the urban Indian population, especially for designing fitness programs for untrained and trained individuals, where stepping is included as an exercise activity.

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