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Cardiorespiratory Fitness in Middle-aged Men and Women through the Queens College Step Test: A Cross-sectional Study

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ABSTRACT

Introduction: Increased Body Mass Index (BMI) is associated with a decreased level of maximium oxygen uptake (VO_2 max), which indirectly affects Cardiorespiratory Fitness (CRF) in young adults. Therefore, it is important to assess CRF in the middle-aged population, despite a high burden of cardiovascular risk factors in this age group. CRF refers to the circulatory system's ability to supply oxygen to functioning muscles during continuous physical exercise. Maximum oxygen uptake (VO_2 max) is the best measure of CRF and serves as the gold standard for quantifying an individual's aerobic capacity.

Aim: To evaluate CRF in middle-aged men and women.

Materials and Methods: The present cross-sectional study conducted in the Department of Physiotheraphy, NITTE Institute of Physiotheraphy included a total of 134 subjects aged between 45 and 65 years, who were selected from Justice KS Hegde Charitable Hospital in Mangaluru, Karnataka, India. The male and female groups consisted of 67 subjects each. The study was conducted over a period of 12 months, from March 2022 to March 2023. All subjects were included based on specific inclusion criteria. VO_2 max was estimated by following the Queens College Step Test (QCST) method. The Pearson's correlation coefficient was used to examine the relationship between age, height, weight, BMI, waist-to-hip ratio, heart rate, and VO_2 max. A p-value <0.05 was considered statistically significant.

Results: The mean value of VO_2 max was assessed and compared between middle-aged males (65.8±3.5 mL/kg/min) and females (46.6±1.7 mL/kg/min). It was discovered that VO_2 max was significantly higher in middle-aged males than in middle-aged females (p<0.001), as indicated by heart rate changes from pretest to post-test. The mean value of BMI was compared between males (24.4±3.2) kg/m^2 and females (24.4±4.9) kg/m^2, and the difference was found to be statistically non significant (p-value=0.916). Similarly, the mean value of waist-to-hip ratio was compared between males (0.9±0.1) and females (0.9±0.1), and the difference was also statistically non significant (p-value=0.637).

Conclusion: Middle-aged males exhibit substantially higher VO_2 max compared to middle-aged females (p<0.001). Consequently, middle-aged females demonstrate a considerable decrease in aerobic capacity, as indicated by VO_2 max, and decreased cardiovascular fitness, which serve as predictors of cardiovascular disease risk factors.

Keywords: Aerobic capacity, Cardiovascular fitness, Maximium oxygen uptake, Middle age, Physical activity

INTRODUCTION

Cardiorespiratory Fitness (CRF) refers to the capacity of the circulatory system to supply oxygen to working muscles during continuous physical activity [1]. The maximum amount of oxygen an individual can inhale and use to produce energy, i.e., Adenosine Triphosphate (ATP) aerobically, is known as VO_2 max [2].

VO_2 max is often used as a marker of physical fitness and is considered a reliable indicator of aerobic fitness [3]. One practical field test for assessing individuals' aerobic fitness is the step test, which provides an estimation of VO_2 max [4]. VO_2 max can be calculated using either maximal or submaximal exercise tests. Walking or running tests are the most commonly used, followed by cycling and step tests [5]. VO_2 max is frequently estimated using prediction equations rather than direct measurements because they are less expensive and easier to perform. For males: VO_2 max=111.33-(0.42×pulse rate beats/min), and for females: VO_2 max=65.81-(0.1847×pulse rate beats/min) [6].

One of the global pandemics is physical inactivity, with more than 30% of adults failing to achieve a meaningful level of daily activity [7,8]. Non communicable diseases such as coronary heart disease and type 2 diabetes mellitus are major causes of death. Furthermore, physical inactivity is responsible for 6% to 10% of all deaths [9].

Moreover, low CRF is linked to an increased risk of cardiovascular disease, which contributes to adult mortality. CRF is an important aspect of health that has been shown to decline non linearly with age. Lower CRF levels are associated with a shorter life expectancy, higher healthcare costs, and poor clinical outcomes [10,11].

Measurements of body weight (anthropometry) are used in clinical settings to reflect body fat, as these measurements provide a rapid and cost-effective way to estimate body fat [12]. In general, using heart rate to predict VO_2 max is simple and reliable [13]. Exercise testing is an important clinical tool for assessing cardiorespiratory fitness and predicting future adverse cardiovascular events [14]. The QCST is a modified version of the Harvard step test, where individuals step up and down on a 16.25-inch/41.3 cm platform at a rate of 22 steps per minute for females and 24 steps per minute for males for three minutes. In the Harvard step test, individuals step up and down on a 20-inch platform for males and a 16-inch platform for females for five minutes [2].

Hence, the present study emphasises CRF in terms of maximum aerobic capacity (VO_2 max) among middle-aged men and women. A previous study reported an association between increased BMI and decreased VO_2 max, which indirectly affects CRF in young adults [11]. Therefore, it is important to assess CRF in the middle-aged population, despite the high burden of cardiovascular risk factors in this age group. The available evidence on using the QCST procedure to estimate VO_2 max in the middle-aged population is of very low certainty [15].

The QCST has high reliability and validity, is cost-effective, consumes less time, and does not require a special laboratory setting compared to other practical field tests. If this study demonstrates a significant difference in CRF between middle-aged men and women, it could highlight the importance of maintaining normal BMI and body fat percentage to improve VO_2 max through physical activity, thereby preventing cardiovascular risk factors. The main aim of present study is to evaluate CRF in middle-aged men and women and to assess and compare CRF in terms of maximum aerobic capacity (VO_2 max) using the QCST.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Physiotheraphy, NITTE Institute of Physiotheraphy at Justice KS Hegde Charitable Hospital in Mangaluru, Karnataka, India. The study was carried out from March 2022 to February 2023. Ethical clearance for the study was obtained from the Institutional Ethics Committee of the Institute with reference number NIPT/IEC/Min/08/2021-22 prior to data collection.

Sample size calculation: The sample size was calculated based on the Standard Deviation (SD) of VO_2 max in males (6.26) and females (3.71) [5]. With a mean difference of 2.5, effect size of 0.5015, alpha error of 5%, and power of 80% for a two-sided hypothesis, the sample size in each group was determined to be 67, resulting in a total of 134 subjects. This calculation was performed using nMaster software version 2.0.

Inclusion criteria: The study included participants between the ages of 45-65 years (middle age group) who were willing to participate and screened based on the PAR-Q+ 2021 questionnaire. Both males and females without any history of previous cardiac surgeries or cardiovascular complications were included.

Exclusion criteria: Participants with knee osteoarthritis, recent lower limb fractures or surgeries, and previous history of cardiovascular complications such as myocardial infarction, coronary heart disease, diabetes mellitus, and hypertension were excluded from the study.

Study Procedure

A total of 134 eligible participants were enrolled in the study. The objective and protocol of the study were explained, and written consent was obtained from the participants. The PAR-Q+ 2021 questionnaire was used to screen the participants [16]. Anthropometric data, such as age and height measured using a height meter, weight measured using a digital weighing machine, and BMI, were recorded [4]. Body fat percentage was calculated using the waist-to-hip ratio, as skinfold calipers were not available. Pretest heart rate was noted. The QCST [17,18], a modified version of the Harvard step test, was performed, where participants stepped up and down on a 16.25-inch/41.3 cm platform at a rate of 22 steps per minute for females and 24 steps per minute for males for three minutes. After completing the activity, the post-test heart rate was recorded, and VO_2 max was computed using the appropriate equation [2].

STATISTICAL ANALYSIS

The collected data were summarised using descriptive statistics, including frequency, percentage, mean, and standard deviation. The independent sample t-test was used to compare age, height, weight, BMI, waist-to-hip ratio, and VO_2 max between males and females. The paired t-test was used for the pre-to-post-test comparison of heart rate. The Pearson's correlation coefficient was used to determine the relationship between age, height, weight, BMI, waist-to-hip ratio, heart rate, and VO_2 max. A p-value less than 0.05 was considered significant. Data were analysed using Statistical Packages for Social Sciences (SPSS) software (SPSS Inc.; Chicago, IL) version 26.0.

RESULTS

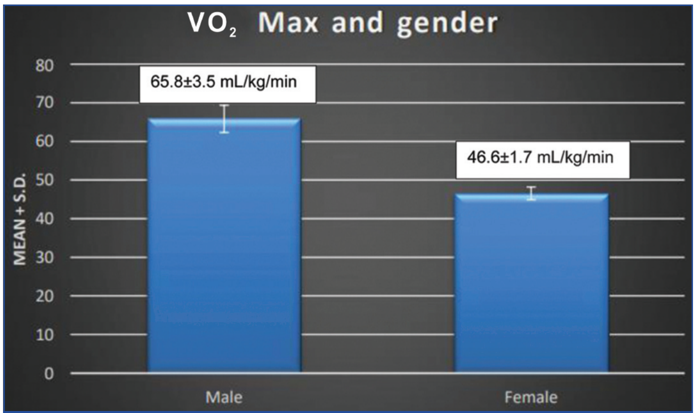
The present study was conducted among 134 middle-aged individuals, including 67 (50%) males and 67 (50%) females. The participants' ages ranged from 45 to 65 years, with a mean of 54.9±5.0 years. Height ranged from 142 to 186 cm, with a mean of 160.6±9.1 cm. Weight ranged from 32 to 94.3 kg, with a mean of 62.8±10.4 kg. BMI ranged from 14.4 to 35.6 kg/m^2, with a mean of 24.4±4.2 kg/m^2 Waist-to-hip ratio ranged from 0.49 to 1.4, with a mean of 24.4±4.2 cm. VO_2 max ranged from 42 to 73.1, with a mean of 56.2±10 [Table/Fig-1].

Parameters	Range	Mean	SD
Age (years)	45 to 65	54.9	5.0
Height (cm)	142 to186	160.6	9.1
Weight (kg)	32 to 94.3	62.8	10.4
BMI (kg/m^2)	14.4 to 35.6	24.4	4.2
Waist-to-hip ratio (cm)	0.49 to1.4	0.9	0.1
VO_2 max. (mL/kg/min)	42 to73.1	56.2	10.1

[Table/Fig-1]: Descriptive statistics for age, height, weight, BMI, waist-to-hip ratio and VO_2 max.
BMI: Body mass index

The study revealed that the mean value of VO_2 max was 65.8±3.5 mL/kg/min for middle-aged males and 46.6±1.7 mL/kg/min for females. There was a significant difference in VO_2 max between middle-aged males and females (p<0.001) [Table/Fig-2].

The paired t-test was used for the pre-to-post-test comparison of heart rate. There was a significant difference (p<0.001) in heart rate from the pretest to the post-test [Table/Fig-3].



[Table/Fig-2]: Represents VO_2 max comparison between male and female.

Variable		Mean	SD	t	p-value
Heart rate	Pretest	96.0	8.1	-19.289	<0.001*
	Post-test	105.9	8.0		

[Table/Fig-3]: Pre to post-test comparison of heart rate.
(t=Paired t-test; *Significant) (p<0.05)

The Pearson's correlation coefficient was used to determine the relationships between age, height, weight, BMI, waist-to-hip ratio, heart rate, and VO_2 max among males. Age was positively correlated with weight (p=0.006) and BMI (p=0.033) among males. Height was positively correlated with weight (p<0.001) and heart rate (pretest) (p=0.001). Weight was positively correlated with BMI (p<0.001) and heart rate (post-test) (p=0.028). Additionally, a positive correlation was found between BMI and waist-to-hip ratio (p=0.038) [Table/Fig-4].

The Pearson's correlation coefficient was used to determine the relationships between age, height, weight, BMI, waist-to-hip ratio, heart rate, and VO_2 max among females. Height was negatively correlated with BMI (p=0.002). Weight was positively correlated with waist-to-hip ratio (p<0.001), heart rate (pretest) (p=0.008), heart rate (post-test) (p=0.002), BMI (p<0.001), and negatively correlated with VO_2 max (p=0.002). BMI was positively correlated with waist-to-hip ratio (p=0.001), heart rate (post-test) (p=0.001), and VO_2 max (p=0.001). A negative correlation was found between heart rate (both pretest and post-test) and VO_2 max among females (p<0.001) [Table/Fig-5].

Male			Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)	Waist-to-hip ratio (cm)	Heart rate (minute)		VO$_2$ max
								Pretest	Post-test	
Age		"r"	1	0.095	0.332	0.260	-0.039	-0.107	0.021	-0.014
		p-value	--	0.443	0.006*	0.033*	0.757	0.387	0.868	0.910
Height		"r"		1	0.433	-0.399	-0.090	0.253	0.185	-0.199
		p-value		--	<0.001*	0.001*	0.471	0.039*	0.133	0.106
Weight		"r"			1	0.649	0.169	0.188	0.268	-0.199
		p-value			--	<0.001*	0.171	0.128	0.028*	0.106
BMI		"r"				1	0.255	-0.031	0.132	-0.050
		p-value				--	0.038*	0.806	0.288	0.689
Waist-to-hip ratio		"r"					1	-0.070	0.018	-0.076
		p-value					--	0.572	0.884	0.542
Heart rate	Pre	"r"						1	0.608	-0.498
		p-value						--	<0.001*	<0.001*
	Post	"r"							1	-0.629
		p-value							--	<0.001*
VO$_2$Max		"r"								1
		p-value								--

[Table/Fig-4]: Relation between age, height, weight, BMI, waist-to-hip ratio, heart rate and VO$_2$ max among males.
("r"=Pearson's correlation coefficient; *Significant)

Female			Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)	Waist-to-hip ratio (cm)	Heart rate (minute)		VO$_2$ max
								Pretest	Post-test	
Age		"r"	1	-0.184	-0.021	0.087	0.148	0.073	0.136	-0.136
		p-value	--	0.136	0.864	0.485	0.232	0.557	0.272	0.272
Height		"r"		1	0.151	-0.377	-0.028	0.184	-0.024	0.024
		p-value		--	0.221	0.002*	0.823	0.135	0.849	0.844
Weight		"r"			1	0.854	0.402	0.319	0.377	-0.377
		p-value			--	<0.001*	0.001*	0.008*	0.002*	0.002*
BMI		"r"				1	0.400	0.229	0.386	-0.385
		p-value				--	0.001*	0.063	0.001*	0.001*
Waist-to-hip ratio		"r"					1	0.093	0.020	-0.020
		p-value					--	0.454	0.874	0.875
Heart rate	Pre	"r"						1	0.763	-0.763
		p-value						--	<0.001*	<0.001*
	Post	"r"							1	-1
		p-value							--	<0.001*
VO$_2$Max		"r"								1
		p-value								--

[Table/Fig-5]: Relation between age, height, weight, BMI, waist-to-hip ratio, heart rate and VO$_2$ max females.
("r"=Pearson correlation coefficient; *Significant)

DISCUSSION

The middle-aged population is more susceptible to developing cardiovascular complications, which is a leading cause of mortality and morbidity worldwide. Obesity and cardiorespiratory fitness are controllable and independent risk factors for cardiovascular death. Maximal oxygen uptake (VO$_2$ max) is the extreme amount of oxygen consumption attained during strenuous exercise. Therefore, VO$_2$ max is widely accepted as a parameter for measuring an individual's cardiopulmonary status [8]. The QCST is one of the most widely used field tests for estimating VO$_2$ max [16,18].

The current study disclosed that the mean value of VO$_2$ max for middle-aged males (65.8±3.5 mL/kg/min) and females (46.6±1.7 mL/kg/min) was assessed and compared. It was found that VO$_2$ max was significantly higher in middle-aged males compared to middle-aged females. This suggests that a decrease in VO$_2$ max can be a reliable indicator of reduced exercise or aerobic capacity in middle-aged females, which, in turn, can lead to further cardiovascular complications.

Similar results were demonstrated by Koju B et al., who conducted a study comparing the mean value of VO$_2$ max in young adult males and females. They found that VO$_2$ max was significantly higher in young adult males compared to young adult females. The study mainly conducted on medical students and aimed to assess and compare the effect of various physical and academic parameters on cardiorespiratory fitness, specifically in terms of maximum aerobic capacity (VO$_2$ max) [11].

In the present study, the mean values of pretest (96.0±8.1) and post-test (105.9±8.0) heart rates were compared, and a significant difference was found between the two. The heart rate showed a significant increase after the strenuous exercise. The present finding is consistent with the study by Leeper NJ et al., who suggested that the heart rate increase at peak exercise is strongly associated with heart rate recovery, which is estimated using treadmill testing and maximum exercise exertion [19].

The current study compared the mean values of BMI in males (24.4±3.2) kg/m² and females (24.4±4.9) kg/m² and found no significant difference between the BMI of middle-aged males and females. BMI is a commonly used anthropometric tool for assessing body fat percentage. However, it has limitations in differentiating between fat mass and muscle mass in individuals.

A study conducted by Singh SK and Dubey PP analysed and compared BMI among males and females in the age group of 15 to 75 years. Their findings revealed a considerable difference in BMI between males and females. They also found a higher proportion of females with high BMI compared to males across all age groups [20].

The current research compared the mean values of waist-to-hip ratio in males (0.9±0.1) and females (0.9±0.1) and found no statistically significant difference. Waist-to-hip ratio is an anthropometric measurement used to assess body fat distribution in individuals.

A review conducted by Stevens J et al., conducted a review on association between gender, age, and waist circumference. The review revealed that waist circumference and waist-to-hip ratio increase with aging in both males and females. It concluded that males tend to have a larger increase in waist circumference with weight gain compared to females [21].

In present study, there was a significant increase in aerobic capacity, as measured by VO_2 max, in middle-aged males compared to middle-aged females. The reduced maximum aerobic capacity in middle-aged females may be attributed to the fact that most of the female participants in the current study were in the age group of 45 to 65 years, which is the menopausal age group. Postmenopausal women experience physiological changes that can impact the cardiovascular system and potentially decrease exercise or aerobic capacity in middle-aged females.

Limitation(s)

The biomechanical characteristic such as height varies among individuals, with taller people having a potential advantage in performing QCST compared to individuals with shorter stature.

CONCLUSION(S)

It was indicated that there was a statistically significant difference between the pretest and post-test heart rates, indicating a change in heart rate from pretest to post-test. Furthermore, no significant difference was found in BMI or waist-to-hip ratio between both genders. The study concluded that VO_2 max in middle-aged males is significantly higher than in middle-aged females. Hence, middle-aged females experience a considerable decrease in aerobic capacity, which is reflected in their lower VO_2 max and decreased cardiovascular fitness. This decrease in cardiovascular fitness serves as a predictor of cardiovascular disease risk factors. However, individuals can improve their VO_2 max by indulging in regular physical activity and exercise, which can ultimately lead to increased cardiovascular fitness.

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