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The Relationship between Selected Anthropometric Indices and Cardiorespiratory Fitness in Apparently Healthy Young Adults in a Nigerian Community

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Authors' contributions

This work was carried out in collaboration between all authors. Authors CNO and AVE designed the study, wrote the protocol and wrote the first draft of the manuscript. Author MJN managed the literature searches and data collection. Authors YEI and UPO helped in statistical data analysis, meanwhile authors CNO and AVE also helped in drafting the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Background and Aim: Cardiorespiratory fitness (CRF) is a useful tool for establishment of baseline fitness status and monitoring of physical activity level. Therefore, it may by extension serve as health risk index. However, studies that have determined the correlation between anthropometric indices and CRF in apparently healthy young adults is difficult to find in other to preempt preventive actions before pathology develops.

Materials and Methods: Using a descriptive correlational research design, 325 participants (160 males, 165 females) with mean age of 21.87±2.41 years were sampled. Tape measure, stop watch, metronome, sphygmomanometer, stethoscope, height meter, bathroom weighing scale, modified Borg's exertion scale and step benches were used to obtain the blood pressure, heart rate, respiratory rate, rate of perceived exertion, height, weight, waist circumference and

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cardiorespiratory fitness was estimated using the mean heart rate responses of the participants. The data was summarized using frequency count, percentages, range, mean, standard deviation, Independent t-test and Pearson's Product Moment Correlation at alpha level of 0.05.

Results: CRF significantly correlated with post-test systolic blood pressure (p= 0.004), post-test diastolic blood pressure (p= 0.010) and resting heart rate (p= <0.0001) but not with BMI (p= 0.133), waist circumference (p= 0.098), pre-test systolic blood pressure (p= 0.155), pre-test diastolic blood pressure (p= 0.121), resting respiratory rate (p= 0.631), and respiratory rate recovery (p= 0.478).

Conclusion: CRF can be used as an index to quantify in apparently healthy participants, level of cardiovascular and respiratory related disease risks. It is necessary to emphasize the importance of physical activity in order to improve one's cardiorespiratory fitness and minimize the risk of cardiorespiratory associated diseases.

Keywords: Cardiorespiratory fitness; body mass index; waist circumference.

1. INTRODUCTION

Cardiorespiratory fitness is the ability of the cardiorespiratory system to supply oxygen to the skeletal muscles during sustained physical activity and can be a useful tool in promoting health [1]. It is important in establishing baseline of fitness; in monitoring change; and in serving as health risk index [2]. However, poor cardiorespiratory fitness (CRF) is associated with increased cardiovascular disease (CVD) [3] which is a leading cause of mortality and morbidity worldwide [1]. Recently, studies have shown that improvement in CRF results in decreased risk of CVD such as hypertension, cardiomyopathies and other comorbidities like diabetes and hypercholestinemia [4-6].

Technological advancements and modern day conveniences have driven most people into sedentary life style leading to a rise in chronic non-communicable diseases like hypertension, chronic heart failure, diabetes mellitus, metabolic syndrome, chronic low back pain and obesity [2]. These preventable non-communicable diseases is associated with deterioration of the individuals CRF [1]. Unfavorable cardiovascular risk profiles have been reported in youths with poor cardiovascular fitness and high percentage body fat [4,5]. Previous studies have also shown that risk factors for cardiovascular disease such as hypertension, diabetes and hypercholesterolemia may influence cardiorespiratory fitness [4] and these risk factors may mediate the association between poor cardio-respiratory fitness and mortality [6]. Earlier studies have demonstrated the role of poor CRF in young adults as a risk factor for developing cardiovascular co-morbidities later in life [3,7-8]. More so, It has been reported that low cardiorespiratory fitness may be associated with premature mortality in individuals classified as normal-weight, overweight, or obese [9]. The observation that cardiorespiratory fitness attenuates obesity-related health risk as measured by central adiposity indices such as body mass index may be explained by differences in abdominal adiposity [10]. Meanwhile, central obesity is defined as accumulation of fat in the abdominal region while Peripheral obesity is defined as accumulation of fat in the hips and thigh region [11-13]. Centrally obese individuals have been reported to be more vulnerable to diseases associated with obesity where as there is proof that peripheral fat distribution may be protective. Conclusively, Central and Peripheral obesity are strong indicators of metabolic disease risk [14,11-13]. Previous studies suggest that weight reduction exercises may be associated with reduction in WC, which is a strong indicator of abdominal obesity [15]. Thus, regular exercise, which improves CRF, may by extension enhance general health and wellbeing [16].

Additionally, maximum volume of oxygen (VO_{2max}) is a primary indicator of aerobic capacity, CRF, cardiovascular health and endurance performance [2]. The CRF of an individual is directly proportional to the individual's aerobic capacity (ability to utilize oxygen during physical activity) as well as VO_{2max}. The direct measurement of VO_{2max} is the criterion measure, or "gold standard" of aerobic capacity where the participant undergoes a maximal exercise test and oxygen consumption is measured directly [8]. Whilst this is the gold standard, the equipment is expensive, impractical in non-laboratory and field-test situations and also requires a high level of technical expertise and supervision. It is also not suitable for individuals for whom exhaustive exercise is not recommended [8]. As a result, numerous tests have emerged for the "estimation" of aerobic capacity. Some are field tests requiring maximum effort, for example the 20 meter multistage shuttle run [16,17] whilst others are submaximal treadmill, cycle or bench-stepping tests with single stage or multistage protocols [16].

Step tests are one of the most widely used field tests for estimating VO_{2max} [18]. Stepping requires no elaborate or expensive equipment, no calibration, and can be easily administered to a large number of people [19-21]. Most commonly administered step tests are performed at a fixed cadence (no of steps per minutes) on a bench of a fixed height [22] ranging from 15-40 centimeters [16,23]. One of such test is the Chester Step Test (CST) which was designed as a submaximal test where heart rate and exertion levels are monitored continuously [24]. The physiological rationale is based on the linear relationship between workload, oxygen consumption and submaximal exercise heart rates, which enables a prediction of VO_{2max} to be made [2]. Several researchers have suggested that, if a step is too high or the test lasts too long, local muscular fatigue may ensue before a true assessment of aerobic capacity can be obtained, so the test may be more a measure of muscular endurance of the legs than of aerobic capacity [18,25-26].

Previous studies have assessed the correlation between anthropometric indices and CRF in patients with chronic cardiovascular diseases or comorbidities. However, studies that have determined the correlation between anthropometric indices and CRF in apparently healthy young adults is difficult to find in other to pre-empt preventive actions before pathology develops.

2. MATERIALS AND METHODS

2.1 Research Design

This study adopted a descriptive correlational research design, involving three hundred and twenty five male and female apparently healthy young adults in a Nigerian community.

2.1.1 Inclusion criteria

Participants were between the ages of 17-40 and certified to have no disease of the cardiovascular, respiratory and nervous systems from a pre-study clinical assessment by a physician. Subjects were considered apparently healthy if they were asymptomatic and believed to be in a good state of health.

2.1.2 Exclusion criteria

Participants were excluded if they had unstable cardiovascular and respiratory system as indicated by their resting blood pressure, heart rate, respiratory rate and capacities; were on antihypertensive drugs or any food and drug that could alter their heart rate.

2.2 Ethical Consideration

Ethical approval was obtained prior to commencement of the study, from the Ethical Review Committee of Nnamdi Azikiwe University Teaching Hospital, Nnewi. The participants had the opportunity of signing an informed consent letter prior to Recruitment to the study.

2.3 Sampling Technique

Consecutive non-probability sampling technique was used to recruit volunteering participants. This technique was used due to the large sample size involved in the study.

2.4 Research Instrument

Measuring tape: This was used to measure the waist circumference.

Stop watch (Kadio model KD-1069, China): It was used to estimate the time taken for the test.

Mechanical metronome and Tempo Perfect Metronome Software v 3.08 NCH Software: It was used to regulate the number of steps per minute during the test. The metronome was set at 96 beats/minute and 88 beats/minute for the male and female participants respectively.

Mercury sphygmomanometer and 3M™ Littmann® Stethoscope: It was used for measuring blood pressure.

Standiometer: This was used to measure the height of the participants.

Bathroom weighing scale (CAMRY): This was used to measure the weight of the participants.

Step bench: This was used for the exercise protocol. Its dimension was 40 cm high; 60 cm long; 30 cm wide and 33 cm high; 60 cm long; 30 cm wide for the male and female participants respectively.

Modified Borg's scale: This comprises of a scale ranging from 6-20 and was used in rating the level of perceived exertion (degree of breathlessness and/or difficult, uncomfortable or labored breathing as well as fatigue level) also referred to as the dyspnea score.

2.5 Experimental Protocol

1. Since the accuracy of the test relies on the heart rate response, participants were instructed to avoid the ingestion of foods and drugs that alter the heart rate (example coffee, soda, energy drinks, beta-blockers) two hours prior to the test.
2. Each participant's initials, age, maximum heart rate (calculated using the Karvonean formula), systolic and diastolic blood pressure, resting heart rate, resting respiratory rate, height, weight, waist circumference, body mass index, rate of perceived exertion, heart rate recovery, respiratory rate recovery and maximum oxygen intake were obtained and recorded accordingly in the test.
3. Before the test, the age, maximum heart rate, blood pressure, heart rate, respiratory rate, height, weight, waist circumference and body mass index were obtained. Using the Modified Borg's scale, the participants were asked to grade their level of shortness of breath before and during the test. Provided the subject showed no overt signs of distress and that the rating of perceived exertion was below 15, the participants were permitted to finish the step test.
4. The metronome was set at 88 beats/min to allow each participant to make contact with a foot on each beep in an up-up, down-down manner. This cadence resulted in 22 steps/min necessary for the test on females and 96 beats/min (24 steps/min) for the males.
5. After this, the 3-minute test began using the stopwatch as a timer and a bench height of 33 cm for females and 40 cm step height for males.
6. To avoid muscle fatigue, the participants were advised to switch the leading leg at least once during the test.
7. After exactly 3 minutes of stepping, participants whose rate of perceived exertion were below 15 stopped the test and the heart rate was taken for 15 seconds after a brief rest of 5 seconds (from 3:05 to 3:20).
8. The predicted VO_{2max} was then calculated using the post-exercise heart rate of the participants using the formula:

   Males: VO_{2max} ($ml.kg^{-1}.min^{-1}$) = 111.33 - (0.42 × HR)

   Females: VO_{2max} ($ml.kg^{-1}.min^{-1}$) = 65.81 - (0.1847 × HR) [26].

2.6 Statistical Analysis

The data from this study was summarized using frequency count, percentages, range, descriptive statistics of mean and standard deviation. The inferential statistics of independent t- test was used to compare the significant difference between the variables of the male and female participants while Pearson's Product Moment Correlation were used to show the relationship between cardiorespiratory fitness and other cardiorespiratory and anthropometric variables of the participants. Level of significance was set at $\alpha = 0.05$.

3. RESULTS

Three hundred and twenty five participants (49% males and 51% females) with mean age and age range of 21.87±2.41 years and 17-40 years respectively, participated in the study.

The mean body mass index (BMI) and cardiorespiratory fitness of the participants were 23.09±3.39 kg/m^2 and 52.97±11.45 $ml.kg^{-1}.min^{-1}$ respectively. The other physical characteristics and the cardiorespiratory parameters of the participants are presented in Table 1.

Cardiorespiratory fitness showed no significant correlation with body mass index (p= 0.133), waist circumference (p= 0.098), pre-test systolic blood pressure (p= 0.155), pre-test diastolic blood pressure (p= 0.121), resting respiratory rate (p= 0.631), and respiratory rate recovery (p= 0.478), but showed a significant correlation with post-test systolic blood pressure (p= 0.004), post-test diastolic blood pressure (p= 0.010) and resting heart rate (p= < 0.0001) (Table 2).

Independent t-test showed that waist circumference (p= 0.001), blood pressure (p= 0.007), heart rate (p= <0.0001) and cardiorespiratory fitness (p= <0.0001) were significantly different between the male and female participants (Table 3).

Table 1. Physical characteristics and cardiorespiratory parameters of the participants (N=325)

Variables	Mean±Standard deviation	Range
Age (years)	21.87±2.41	17-40
Height (m)	1.68 ±0.09	1.47-1-98
Weight (kg)	65.16±10.54	42-120
BMI (kg/m^2)	23.09±3.39	16.49-40.88
WC (cm)	77.77±7.72	49.53-111.76
SBP_1 (mmHg)	112.27±12.24	66-140
DBP_1 (mmHg)	69.97±10.53	30-133
HR_1 (beats/min)	76.55±12.12	48-113
RR_1 (cycles/min)	23.01±3.47	12-36
CRF (ml.kg−1.min−1)	52.97±11.45	30.35-84.21
SBP_2 (mmHg)	121.95±6.08	106-144
DBP_2 (mmHg)	78.83±6.62	60-120
RR_2 (cpm)	36.19±6.69	22-68
HR_2 (bpm)	118.22±19.56	64-192
RPE	12.78±0.70	11-15

Key: N: Number of participants; X: Mean; S.D: Standard deviation; BMI: Body mass index; WC: Waist circumference; RPE: Rate of Perceived exertion; SBP_I: Pre-test systolic blood pressure; DBP_I: Pre-test diastolic blood pressure; HR_I: Resting heart rate; RR_I: Resting respiratory rate; CRF: Cardiorespiratory fitness; HR_2: Heart rate recovery; SBP_2: Pre-test systolic blood pressure; DBP_2: Pre-test diastolic blood pressure; RR_2: Respiratory rate recovery; mmHg: millimeter of mercury; m: meter; kg: kilogram; kg/m²: kilogram per meter square; $ml.kg^{-1}.min^{-1}$: Milliliter per kilogram per minute

Table 2. Pearson's product moment correlation showing the relationship between cardiorespiratory fitness and other cardiorespiratory and anthropometric variables of the participants (N=325)

Variables	r-value	p-value
BMI (kg/m^2)	-0.084	0.133
WC (cm)	0.092	0.098
SBP_1 (mmHg)	0.079	0.155
SBP_2 (mmHg)	0.158	0.004*
DBP_1 (mmHg)	0.086	0.121
DBP_2 (mmHg)	0.143	0.010*
RR_1 (cpm)	-0.078	0.163
RR_2 (cpm)	-0.039	0.478
HR_1 (bpm)	-0.431	<0.0001*

*Key: BMI: Body Mass Index; WC: Waist circumference; SBP_I: Pre-test systolic blood pressure; SBP_2: Post-test systolic blood pressure; DBP_I: Pre-test diastolic blood pressure; DBP_2: Post-test diastolic blood pressure; RR_1: Resting respiratory rate; RR_2: Respiratory rate recovery; HR_1: Resting heart rate *: Significant Correlation; mmHg: millimeter of mercury; kg/m²: kilogram per meter square*

Table 3. Independent t - test comparing the anthropometric and cardiorespiratory parameters of the male and female participants

Variables	Males (N=160) X± S.D	Females (N=165) X± S.D	t- value	p - value
BMI	23.14±3.48	23.05±3.31	0.230	0.818
WC	31.16±2.98	30.09±3.01	3.227	0.001*
SBP_1	114.13±12.14	110.46±12.11	2.730	0.007
DBP_1	71.26±10.74	68.72±10.20	2.188	0.029*
RR_1	22.84±3.70	23.16±3.24	-0.831	0.407
HR_1	71.73±11.55	81.22±10.79	-0.766	0.000*
CRF	62.17±8.65	44.04±4.85	23.416	0.000*

*Key: N: Number of participants; X: Mean; S.D: Standard deviation; BMI: Body mass index; WC: Waist circumference; SBP_1: Pre-test blood pressure; DBP_1: Pre-test diastolic blood pressure; RR_1: Resting respiratory rate; HR_1: Resting heart rate; CRF: Cardiorespiratory fitness; *: Significant correlation*

4. DISCUSSION

The present study evaluated the relationship between anthropometric indices and cardiorespiratory fitness in apparently healthy young adults in Otolo-Nnewi community, Anambra State, Nigerian; using the Chester Step Bench Test. Few studies have investigated the relationship between obesity and cardiorespiratory fitness [1,7]. However, it was suggested in these studies that cardiorespiratory fitness (CRF) is associated with lower abdominal fat, independent of body mass index (BMI) and thus emphasized the influence of central obesity, measured using waist circumference, in determining an individual's cardiorespiratory fitness level [7].

The significant observation that males had higher cardiorespiratory fitness than female participants is in line with previous studies [13,15]. This is not surprising as anatomical variations have offered males larger heart surface area and improved pumping efficiency than the females who in addition to smaller heart surface area, have smaller lung volume, expiratory flow limitation and a high work of breathing than males [27,28]. This implies that the bio-physiological make up of males gives them an edge over their female counterparts. It has also been previously reported that females are more unlikely to participate in physical activities than their male counterparts [29].

A primary finding of this study is the significant negative correlation between cardiorespiratory fitness and resting heart rate which is well documented in previous literature [30,31]. The heart grows stronger through endurance training and pumps blood more forcefully, pushing more volume of blood through the muscle per beat. This is not surprising as physically fit individuals tend to have improved pumping efficiency of the heart, which makes it possible for their cardiorespiratory system to deliver the same amount of oxygen, transported by red blood cells, to working muscles with less heart beats [32]. Additionally, this may also explain the significant negative correlation between cardiorespiratory fitness and post-test systolic and diastolic blood pressures reported which also agrees with the studies by [33-35]. The improved cardiorespiratory efficiency as seen in individuals with improved cardiorespiratory fitness also translates to reduced peripheral vascular resistance.

On the other hand, the present study showed no significant correlation between cardiorespiratory fitness and each of body mass index and waist circumference. This is contrary to some previously related studies [1,16,36] in which cardiorespiratory fitness positively correlated with each of body mass index and waist circumference. However, the use of a calculated value for VO_2Max, rather than a direct measure, may have contributed to the non-significant association found in the present study. Since, it was clear from previous studies that physical activity conveys health benefits independent of concomitant CRF improvement and reductions in body weight and adiposity indices.

The significant difference in the pre-test systolic and diastolic blood pressure of the male and female participants is consistent with the report of a previous study [37] which showed that males have higher blood pressure than their female counterparts suggesting that males are at greater risk of cardiovascular and respiratory disease than age-matched pre-menopausal females. Although the mechanisms responsible for the gender differences in blood pressure control is not clear, there is also significant evidence that testosterone plays a role in gender associated differences in blood pressure regulation [38,39] because studies using ambulatory blood pressure monitoring techniques in young adults have reported that blood pressure was at least 4 mmHg higher in males than in females. More so, previous studies have shown that women with polycystic ovarian syndrome characterized by elevated testosterone levels experiences hypertension [40-42].

Male participants had slightly higher waist circumference than their female counterparts though this was not significant. Males have been found to have a relatively more central distribution of fat due to the influence of the sex hormone level [43]. Males are also more likely to accumulate adipose tissue in the intra-abdominal cavity (apple pattern) while females accumulate adipose tissue in the gluteal/femoral deposits (pear pattern) [44] and this predicts greater cardiorespiratory health related risks for men [44,45].

There was no significant difference between the body mass indices of male and female participants which is contrary to previous reports [1,7]. However, females have been found to have higher body mass index than males from age 7 to 16. After age 18, the body mass index values of males become slightly greater than that of females owing to the fact that males tend to have more muscle mass than the females [46]. Female participants had slightly higher resting respiratory rate (RR_1) than their male counterparts as opposed to [29] though this was not significant. This may be attributed to the more number of female participants in the study compared to the males.

5. CONCLUSION

This study reveals that moderate to high cardiorespiratory fitness results in improved pumping efficiency of the heart and reduces the risk of cardiorespiratory associated diseases across categories of physiological state, body composition and age in young people. More so, being fit may reduce the hazards of poor cardiorespiratory fitness.

6. LIMITATIONS OF THE STUDY

A limitation of the study was that the researcher could not prevent the participants from avoiding the use of foods and drugs that may have altered their cardiorespiratory variables two hours prior to the test. Additionally, the researcher calculated the value for VO_2max, rather than using direct measurement as means to estimate maximum oxygen intake of the participants.

7. RECOMMENDATION

Based on the findings of this study, the following recommendations were made:

1. There is need to emphasize the importance of physical activity in order to improve one's cardiorespiratory fitness and minimize the risk of some diseases associated with low cardiorespiratory fitness.
2. There is also need to advocate and incorporate the assessment of cardiorespiratory fitness using anthropometrics indices as an extrapolation in medical screening, community, and occupational health settings as a measure and monitor of one's health status in our environment.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard or university standard, written approval of Ethics committee has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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