# THE RELATIONSHIP BETWEEN BODY COMPOSITION MEASURES AND PREDICTED MAXIMAL OXYGEN UPTAKE ($VO_2max$) AMONG COLLEGE AGE FEMALES

by

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ABSTRACT

# THE RELATIONSHIP BETWEEN BODY COMPOSITION MEASURES AND PREDICTED MAXIMAL OXYGEN UPTAKE ($VO_2$MAX) AMONG COLLEGE AGE FEMALES

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The physiological and physical capabilities of an individual contribute to their aerobic capacity, also known as fitness. Determination of cardiorespiratory fitness, which is expressed in terms of maximal oxygen uptake ($VO_2$max), depends on health, genetics, training status, exercise mode and the amount of muscle mass involved in the exercise. The purpose of the study was to analyze the relationship between predicted $VO_2$max and body composition measures.

Twenty-one female subjects participated in this study (23.05 ± 4.35 yrs, 64.95 ± 2.96 in, 68.80 ± 14.65 kg). Subjects were asked to report to the University of Texas at Arlington (UTA) Exercise Science Research Laboratory on two separate occasions. Measures of body composition included: body mass index (BMI), percent body fat

(%BF) using bioelectrical impedance (BIA) and %BF using the skinfold measures from seven different sites. These measures were taken during the first visit. On the second visit, a submaximal exercise test was conducted on a bicycle ergometer. The workload or resistance on the bicycle ergometer was increased every two minutes for a total of six minutes. Variables collected during this test included VO2 and heart rate (HR) which were then used to predict maximal values for $VO_2$ and HR.

The results indicated that there was a negative correlation between measures of body composition and predicted $VO_2$max. The correlation coefficient between BMI & $PVO_2$max was -0.64; between %BF (SF) & $PVO_2$max was -0.80 and %BF (BIA) & $PVO_2$max was -0.72. These findings suggest a moderately high, inverse relationship between body composition and predicted maximal oxygen uptake ($PVO_2$max). A lower percent body fat was correlated with a higher $PVO_2$max.

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CHAPTER 1

# INTRODUCTION

## Background

The physiological and physical capabilities of an individual contribute to their aerobic capacity also known as fitness. Determination of cardiorespiratory fitness, which is expressed in terms of maximal oxygen uptake ($VO_2$max), depends on health, genetics, training status, exercise mode and the amount of muscle mass exercised. (Kohrt et al., 1991). Cardiorespiratory fitness refers to the ability of the circulatory and respiratory system to supply oxygen carrying blood to skeletal muscles during sustained physical activity. Maximal oxygen consumption is the maximal rate at which the body can consume oxygen during exercise. It is generally accepted that a person's $VO_2$max is indicative of their maximal cardiorespiratory fitness.

Body composition is known to influence physical performance. Body composition is used to describe the percentages of fat, bone and muscles in human bodies. There are several techniques that can be used to measure body composition. Humans deposit fat underneath the skin and the measurement of the thicknesses of skinfolds can be used to estimate the percentage of the body that is fat. Determining the thickness of skinfolds is done at one or more sites of the body with a pair of skinfold caliper. Bioelectric impedance also provides information about the percentage of body fat. It is a simple procedure that takes just a few minutes to perform. This method involves passing a low level electrical current through the body and measuring the resistance. Lower resistance is associated with less body fat. It has been demonstrated in the literature that there is a close relationship between body composition and maximal oxygen consumption.

Vogel and Friedl (1990) determined that exercise affects body composition. It is generally accepted that successful marathon running performance is associated with a body type that is characterized by leanness and modest muscle mass. This means that athletic performance is related to body dimension and composition. Studies have also investigated the relationship between $VO_2$max and fat free body weight, active tissue, body weight and cell mass (Buskirk et al., 1957; Fahey et al., 1975). These studies demonstrated a high correlation between $VO_2$max and a) fat free body weight ($r = 0.85$) and b) active tissue ($r = 0.91$). A moderate relationship was found between $VO_2$max and body weight ($r = 0.63$) and a low correlation was determined between $VO_2$max and cell mass ($r = 0.45$). Additional studies have been conducted to analyze the effects of health, age, gender, mineral supplements and body composition on an individual's maximal oxygen consumption.

The studies reviewed have been conducted on the relationship between body composition and maximal oxygen uptake; however, few studies have evaluated the relationship between body composition and predicted maximal oxygen consumption ($PVO_2$max). Wyndam (1968) evaluated submaximal tests for estimating maximum oxygen intake, of which it was concluded that estimate was reliable but crude. Sady et al predicted $VO_2$max during cycle exercise in pregnant women (1988). The accuracy of $VO_2$max estimated during this test was compared with values of two popular method: Astrand nomogram and the $VO_2$ versus heart rate ($VO_2$-HR) curve; of which predictions correlated well with ($VO_2$-HR) curve.

There are advantages to using submaximal exercise testing to predict maximal oxygen consumption. These include conducting exercise tests in the research laboratory that take less time and require less exertion on the part of the subject. Chatterjee et al. (2004) and Buckley et al. (2004) also investigated the reliability and validity of aerobic field testing in predicting maximal oxygen uptake ($PVO_2$max). Their results showed that the Queen's College step test, a $VO_2$max test that can be performed in absence of a well-equipped laboratory, is a good estimations of maximal oxygen uptake.

The purpose of the study is to analyze the relationship between predicted maximal oxygen ($VO_2$max) uptake and body composition measures.

CHAPTER 2

# METHODS

## 2.1 Subjects

Twenty-one subjects from the Department of Kinesiology at The University of Texas at Arlington were recruited for this study. The experimental protocol was fully explained to participants and they were asked to sign an informed consent document.

## 2.2 Experimental Design

Subjects were asked to report to the UTA Exercise Science Research Laboratory on two separate occasions. Each visit lasted 30-45 minutes. On the first visit, several measures of body composition were made. On the second visit, the bicycle ergometer test was conducted to predict $VO_2$max.

Body Composition:

*Body Mass Index*: The body mass index (BMI) is based on the ratio of body weight to height ($Kg/m^2$) and has been used to classify an individual's risk for cardiovascular disease.

*Percent Body Fat (Skinfolds):* The percent body fat (%BF) will be determined from skinfolds taken at seven sites (triceps, subscapular, chest, midaxillary, abdominal, suprailiac, and thigh) and using the generalized skinfold equation (Body Density = 1.097 – 0.00046971 (sum of seven skinfolds) + 0.00000056 (sum of seven skinfold)$^2$ – 0.00012828 (age)) (Williams et al., 2000). Body density will then be used to determine percent body fat (%BF).

*Percent Body Fat (Bioelectrical Impedance):* Basic demographic information for each subject will be entered into the BIA which will then be held in both hands until a reading for the %BF is obtained.

Predicted Maximal Oxygen Consumption:

*Submaximal Bicycle Ergometer Test*: Each subject was required to complete three submaximal workloads on a stationary bicycle ergometer. Each workload lasted for two minutes. The workload or resistance that the subject pedaled against increased in 25 watt (W) increments from a starting point of 50 W. During the exercise test, heart rate (HR) was determined using a Polar HR monitor and the amount of oxygen consumed ($VO_2$) was measured using a metabolic cart (SensorMedics). Determination of the $VO_2$ required that the subject wear a headgear supported the flow sensor that was connected to a mouthpiece. This allowed the expired air to be collected in the metabolic cart where the concentrations of oxygen and carbon dioxide were analyzed. The data obtained for the HR and $VO_2$ at each of the three workloads was used to predict $VO_{2max}$ and HRmax.

2.3 Instrumentation

The Health O Meter stadiometer and weight scale were used to obtain the height and weight. The Omron Body Logic Body Impedance Analyzer was used to get the percent body fat and body mass index. The 7-site skinfold data was measured using the Lange skinfold caliper. The SensorMedics cycle ergometer and metabolic cart were used to get the $VO_2$ .

2.4 Statistical Analysis

Variables that were used for analysis included heart rate; body mass index and % BF (body impedance analysis and skinfolds). Heart rate and oxygen consumption ($VO_2$) was recorded every two minutes during the three stages of workload exercise. A simple linear regression equation, $y = mx + c$, was used to determine the $VO_2$max using the age predicted maximal heart rate (HRmax). Using this equation, y was the predicted $VO_2$max, x was the HRmax, c is the intercept and m is the slope of line. A correlation coefficient was calculated to analyze the relationship between predicted $VO_2$max and body composition.


**Diagram 2.1: Polar Heart Rate Monitor**


**Diagram 2.2: Omron Body Logic Body Impedance Analyzer**


**Diagram 2.3: Health O Meter Stadiometer and Weight Scale**


**Diagram 2.4: Lange Skinfold Caliper**

**Diagram 2.5: Bicycle Ergometer**


**Diagram 2.6: A Subject on top of the Cycle Ergometer Strapped to the Sensormedics Metabolic Cart**

CHAPTER 3

# RESULTS

The values for percent body fat derived from the 7 site skinfold, for the collegiate women, ranged from 11% to 38% with an average of 25.90 % ± 7.46. Percent body fat derived from BIA ranged from 13% to 39% with an average of 25.90 % ± 6.82. Body mass index (BMI) ranged from 18 kg/m$^2$ to 36.8kg/ m$^2$ with an average of 25.02 ± 5.18. Age-predicted maximal heart rate (HRmax) ranged from 185 bpm to 201 bpm with an average of 196.95 bpm ± 4.35. Predicted $VO_2$max values for the women ranged from 15.99 ml/kg/min to 44.72 ml/kg/min with an average of 26.81 ml/kg/min ± 7.49 (See Table 3.1).

**Table 3.1: Description of Subject Data**

| | **Age** | **Height** (m) | **Weight** (kg) | **%BF (SF)** | **%BF (BIA)** | **BMI** (kg/m$^2$ | **PHRmax** (bts/min) | **PVO$_2$max** (ml/kg/min) |
|---|---|---|---|---|---|---|---|---|
| Mean | 23.05 | 1.65 | 68.80 | 25.90 | 25.90 | 25.02 | 196.95 | 26.81 |
| SD | ±4.35 | ±0.08 | ±14.65 | ±7.46 | ±6.82 | ±5.18 | ±4.35 | ±7.49 |
| Min | 19 | 1.52 | 50 | 11 | 13 | 18 | 185 | 15.99 |
| Max | 35 | 1.80 | 104.5 | | 39 | 36.8 | 201 | 44.72 |

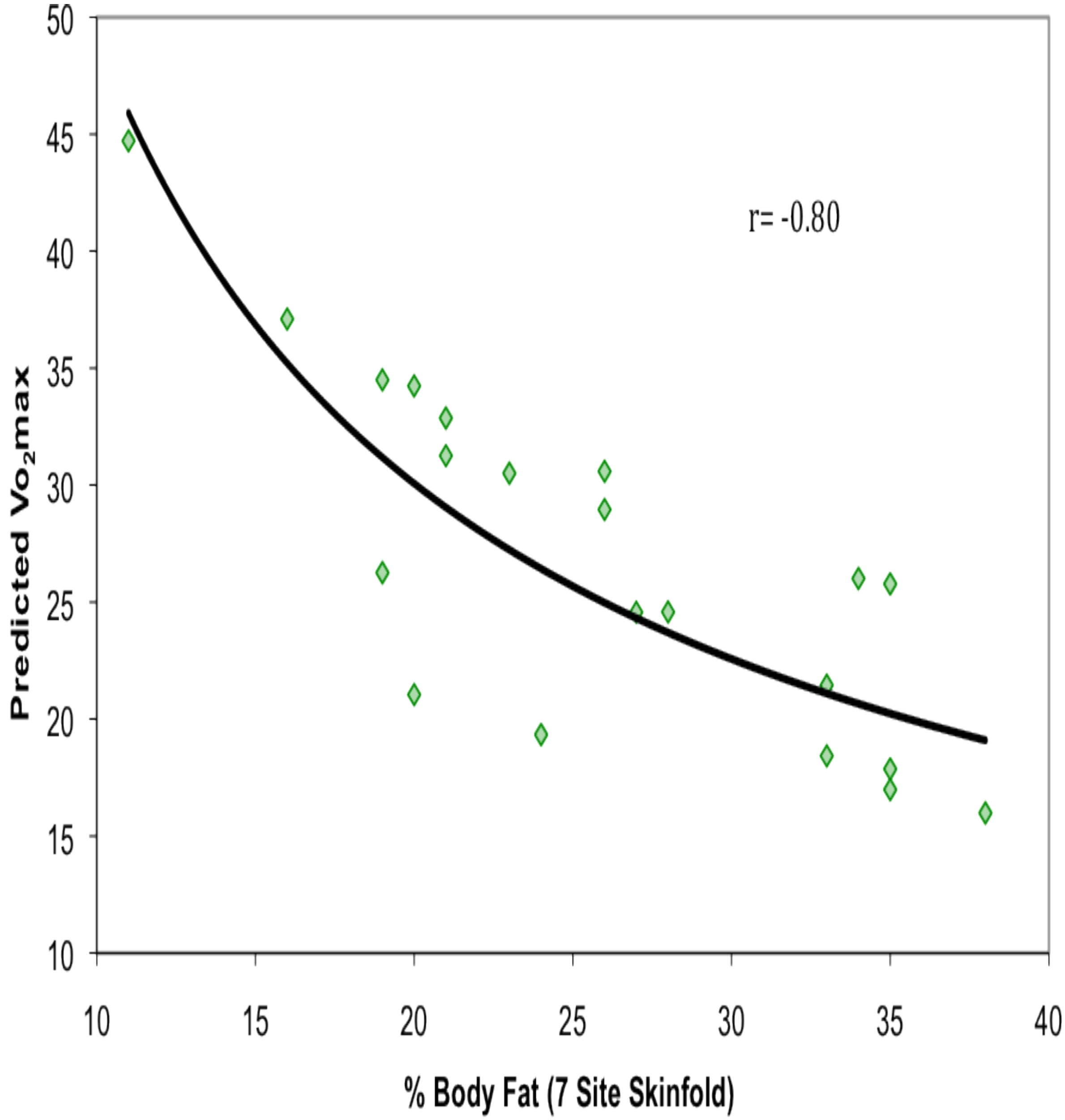


**Figure 3.1: The Relationship Between Percent Body Fat from 7 Site Skinfold and Predicted $VO_2max$**

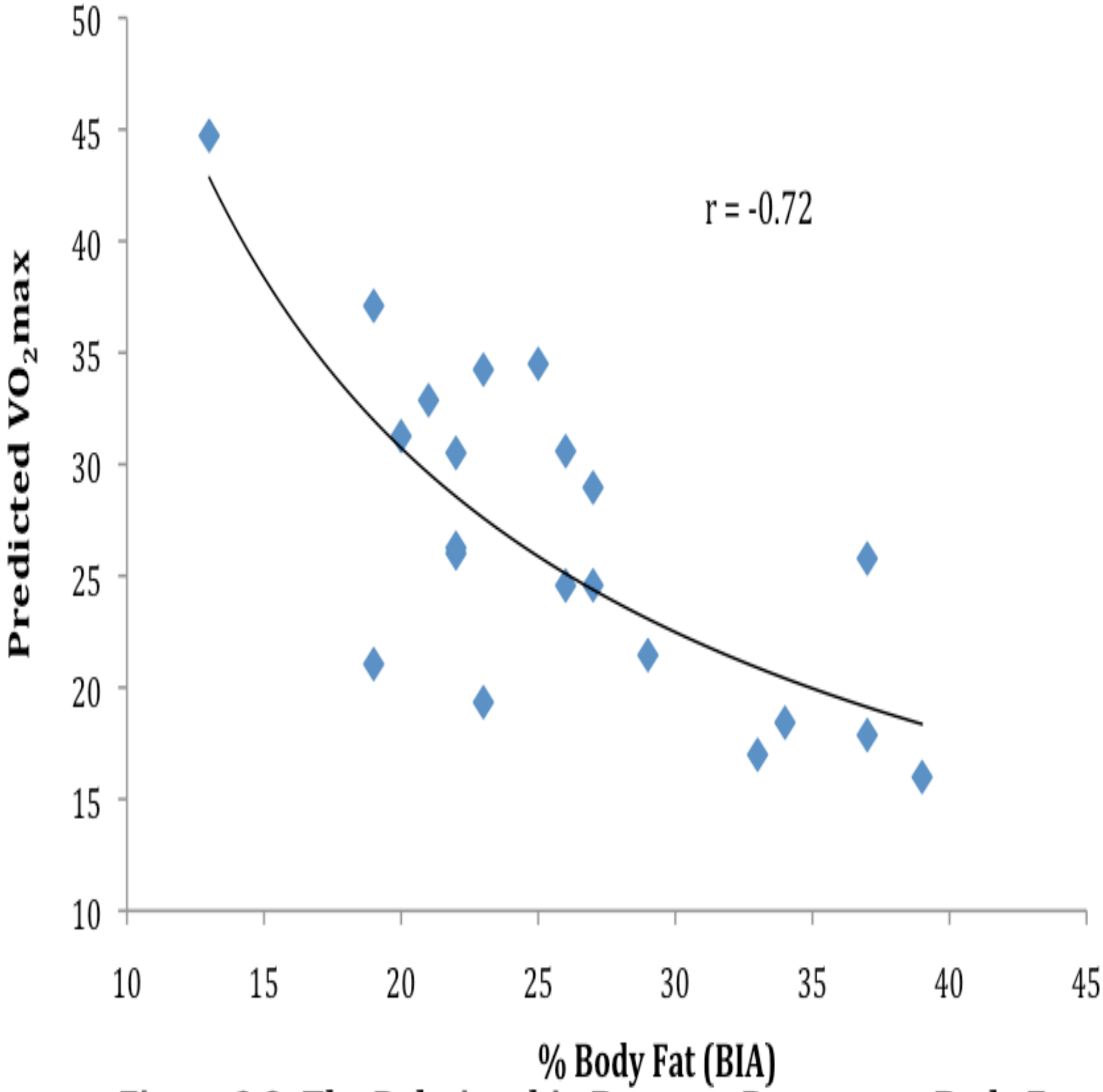


**Figure 3.2: The Relationship Between Percentage Body Fat from BIA and Predicted $VO_2max$**

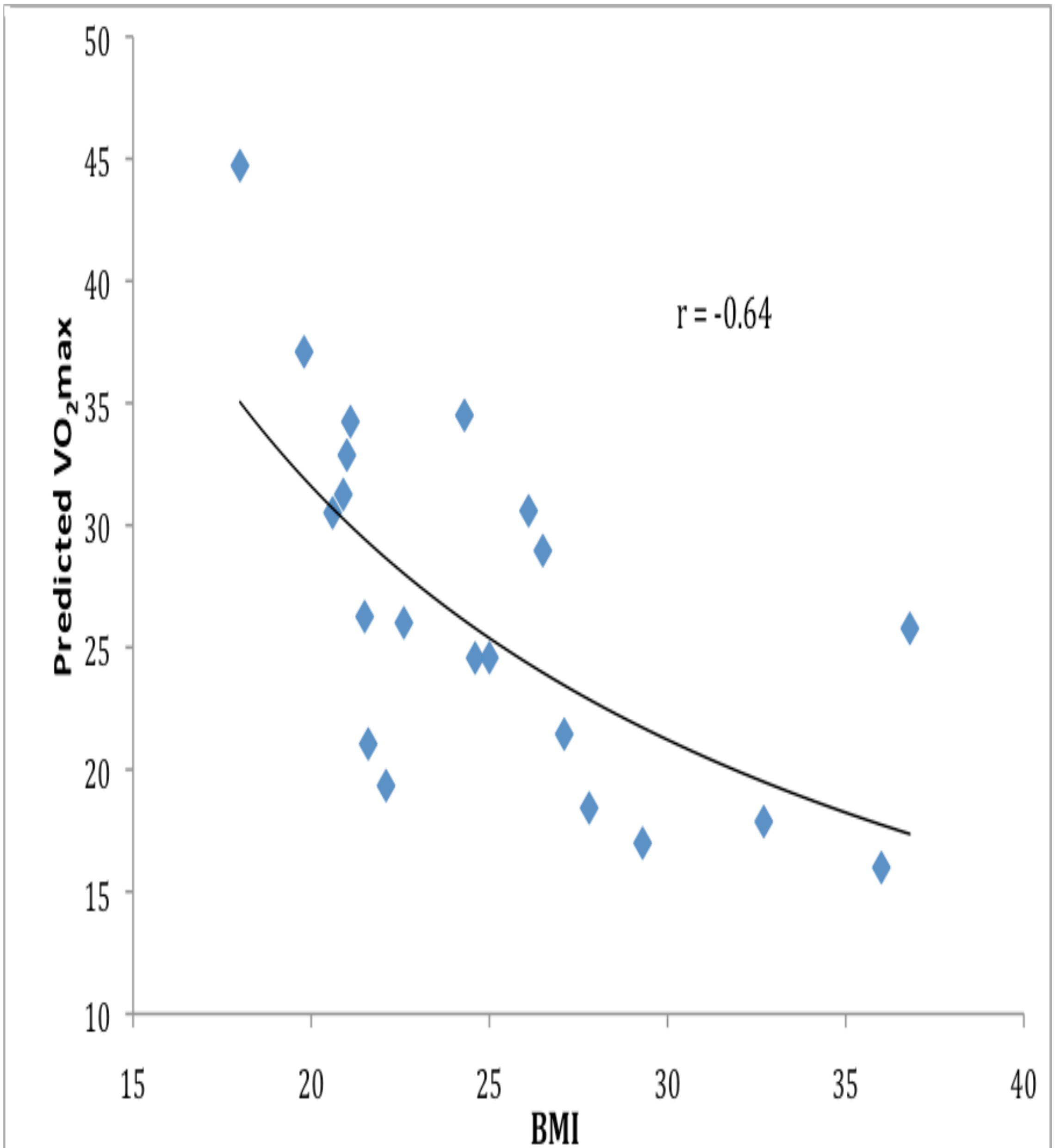


**Figure 3.3: The Relationship Between Body Mass Index and Predicted $VO_2$max**

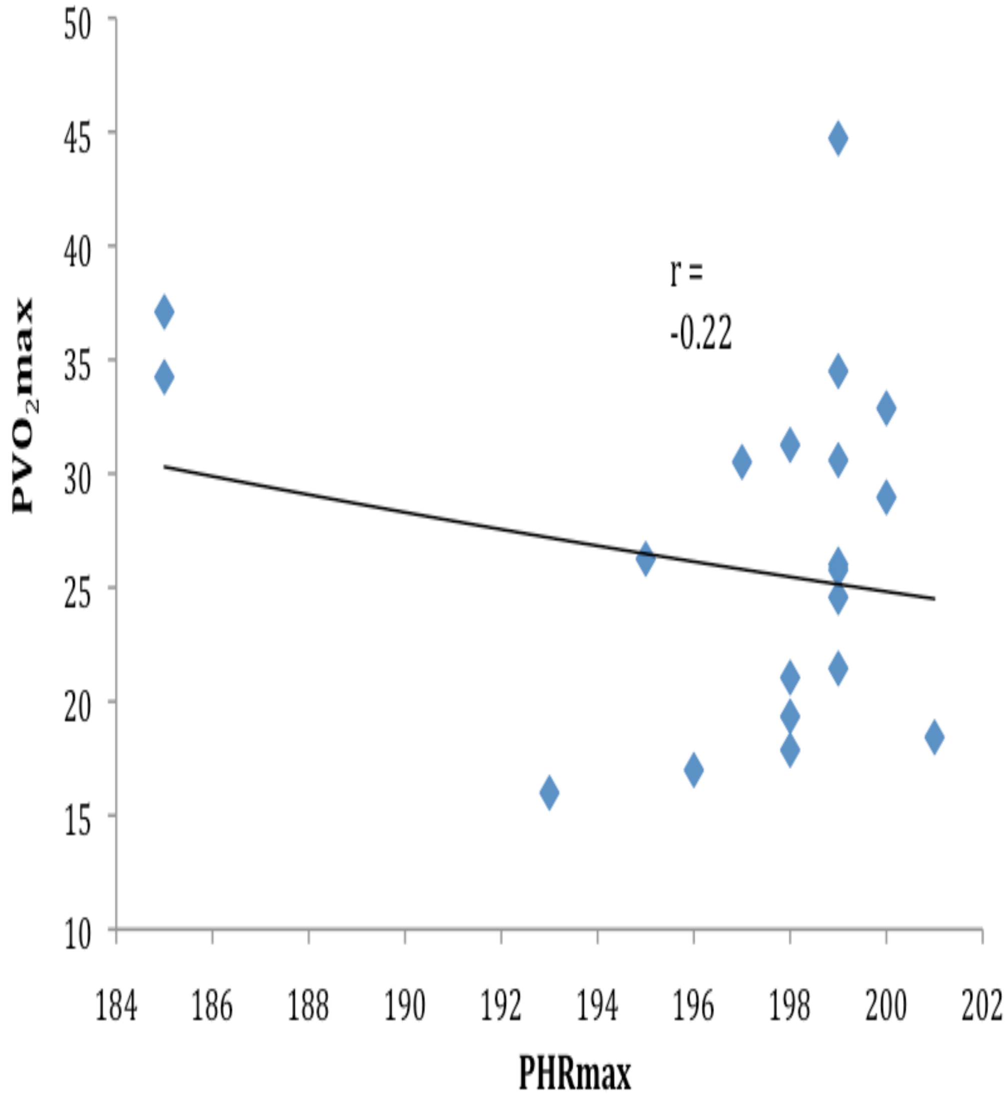


**Figure 3.4: The Relationship Between Age Predicted Maximal Heart Rate and Predicted Maximal Oxygen Uptake**

Inverse correlations were found between the body composition measures and predicted $VO_2max$ and are presented in Figure 1. The correlation between predicted $VO_2max$ and percent body fat derived from BIA was moderately high (r = - 0.72) as was the correlation between predicted $VO_2max$ and percent body fat derived from the 7 site skinfold (r = -0.80). There was a moderate correlation between BMI and predicted $VO_2max$ (r = -0.64).

**Table 3.2: Pearson's correlation coefficients between body composition measures and**

| | **%BF (SF)** | **%BF (BIA)** | **BMI(kg/m$^2$)** |
|---|---|---|---|
| **N** | 21 | 21 | 21 |
| **$PVO_2max$** (ml/kg/min) | -0.80 | -0.72 | -0.64 |

Predicted $VO_2max$ had a low correlation with age predicted HRmax (r = -0.22). See Figure 3.4.

CHAPTER 4

# DISCUSSION

## 4.1 Summary

It is clear that an inverse relationship, as determined by the correlation coefficients, between predicted $VO_2$max and body composition measures is a consistent finding. Although the relationship is moderately high (-0.80, -0.72, -0.64), an increase in body composition means a potential decrease in predicted $VO_2$max. On the other hand, a decrease in the %BF usually results in a potential increase in predicted $VO_2$max. The consistency of these findings and their agreement with the literature using maximal oxygen consumption suggest that the determination of cardiorespiratory fitness in terms of $VO_2$max can be replaced by simpler procedures such as those used by Chatterjee et al. (2002).

The prediction of maximal heart rate, based on the age-predicted HRmax equation: 220-age, did not show a very strong relationship ($r = -0.22$).

In this study, three female subjects were not able to complete the three workloads. They all stopped the test at the beginning of the highest resistance workload (100 watts). Although oxygen consumption ($VO_2$) at six minutes was not recorded, heart values at the time suggested maximal effort from the women. To compensate for this lost data, baseline $VO_2$ was used in the calculation of the predicted $VO_2$max. Other possible errors that might have affected the results during the exercise tests included mechanical failure of the SensorMedics making it impossible to record correct $VO_2$

during the test at certain minutes. The Polar heart rate monitor also failed to report heart rate for one subject at minute 4 and minute 6; heart rate had to be manually determined.

Although predicted $VO_2$max was determined from age predicted HRmax, it should be known that age and gender do not primarily affect predicted $VO_2$max but rather an individual's cardiorespiratory fitness and overall health and wellness. It is possible to increase predicted $VO_2$max through continuous body adaptation response to exercise training (Kohrt et Al., 1991). It is possible that a high percent body fat and a low $VO_2$ max will increase an individual's potential risk of cardiovascular disease. It is therefore recommended that a longitudinal study to test for not only the relationship between predicted $VO_2$max and body composition measures but also potential long term risk of cardiovascular disease be done.

## 4.2 Conclusion

An individual's body composition will have an impact on one's cardiorespiratory fitness while age and gender do not necessarily affect an individual's physical fitness. In this study, a moderately high, inverse relationship between body composition and predicted maximal oxygen uptake ($PVO_2$max) was determined thus indicating that a lower percent body fat was correlated with a higher $PVO_2$max.

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## BIOGRAPHICAL INFORMATION

Olaide was born in Nigeria and spent her early years there before she moved to Texas. She started her college education at Tarrant County College and later transferred to University of Texas at Arlington to further her educational knowledge. As a biology student, she realized that her interest was health and wellness, which made her switch over to Kinesiology.

Wishing to explore her interest through research, Olaide has done various researches related to her field of study under supervision of faculty instructors and mentors like Dr. Mark Ricard, Dr. Judy Wilson and Dr. Abu Yilla. For her senior project she worked under the supervision of Dr. Wilson, Dr. Ricard and Brad Heddins. Her research study had resulted in a poster presentation at the end of the spring undergraduate research program. This will be her second presentation to the Department of Kinesiology. She conducted a research on obesity epidemic among children in Fall 2007. Her study on body composition measures produced the present honor thesis.

Olaide is very grateful for the extraordinary opportunity her mentors and instructors have given her to learn from them and also their help in making sure here research study was outstanding. She hopes to further career by branching to a field of engineering that is of great interest to her- Biomedical Engineering.