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The relationship between body mass index and percent body fat in masters level competitive athletes

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THE RELATIONSHIP BETWEEN BODY MASS INDEX AND PERCENT BODY FAT IN MASTERS LEVEL COMPETITIVE ATHLETES

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health Sciences and Human Performance at Ithaca College has been approved.

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ABSTRACT

Body mass index (BMI) is a tool used widely to estimate body fatness (%BF) and disease risk of an individual. Although BMI is used frequently, it is derived from limited information (height, weight) that does not account for body composition. Consequently, BMI has limited specificity to identify disease risk in subpopulations such as older adults, women, various ethnicities, and athletes. This is problematic because when used as an indicator of risk, BMI can identify individuals who depart from the statistically normal height-weight proportion for age and sex, as having erroneously high risk. To better understand the relationship between BMI and %BF in an older athletic population, BMI and %BF were measured in masters athletes (N = 35, N_{male} = 24, N_{female} = 11), between 45-65 years. Height, weight, waist circumference, BMI, and %BF via hydrostatic densitometry were determined and compared to the general population. Independent samples *t*-tests were used to compare measures of body size and composition between the general population and masters athletes. Results indicated that masters athletes had a significantly lower BMI and waist circumference compared to the general population. A chi-squared analysis for goodness of fit was used to determine the sensitivity and specificity of BMI and waist circumference. Results indicated that for the cut point of 25 $kg \cdot m^{-2}$, BMI was 100% sensitive and 64% specific, indicating that the accuracy of BMI is limited in this population. In summary, masters athletes were more often identified as overweight but were not overfat based on %BF, and had significantly lower BMI and waist circumference when compared to the general population.

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DEDICATION

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CHAPTER 1

INTRODUCTION

Body Mass Index (BMI) is frequently used to identify obesity trends in a population. According to the World Health Organization (WHO) a BMI of less than 18.5 $kg \cdot m^{-2}$ is considered underweight, a BMI of less than 25 $kg \cdot m^{-2}$ is considered normal, a BMI of greater than or equal to 25 $kg \cdot m^{-2}$ is considered overweight, and a BMI greater than or equal to 30 $kg \cdot m^{-2}$ is considered obese (WHO, 2012). The BMI cut points were derived from the relationship between body fat percentage (%BF), BMI, and associated disease risk. That is, a higher BMI is associated with a higher %BF, and greater risk for developing chronic diseases such as, hypertension, diabetes, hyperlipidemia, and coronary artery disease (Jeffreys, McCarron, Gunnell, McEwen, & Smith, 2003). Research indicates that BMI has a moderate to strong correlation with %BF (r = 0.60-0.82), although this relationship is not strong enough to consider BMI a predictor of %BF (Smalley, Kneer, Zebulon, Kendrick, Colliver, & Owen, 1990). For example, a study of 1,626 subjects, used multiple regression to predict %BF from BMI and found that a BMI of 25 $kg \cdot m^{-2}$ corresponded to a %BF of 20% for males and 33% for females (R = 0.86) (Gallagher, Heymsfeld, Moonseong, Jebb, Murgatroyd, & Sakamoto, 2000). This suggests that with a BMI of 25 $kg \cdot m^{-2}$, males and females should average a %BF of 20% and 33%, respectively.

The BMI measure contributes to the risk profile in the general population, but it is not specific enough to accurately predict risk in certain subpopulations such as adolescents, elderly, and athletes (Blew et al., 2002; Dudeja, Misra, Pandey, Kumar, &

Vikram, 2001; Goh, Tain, Yong, Mok, & Wong, 2004). For example, in muscular athletes, BMI can be misleading since body weight is typically comprised of more muscle and less fat compared to the general population. In this case, an athlete could have a high BMI, but low %BF (Ode, Pivarnik, Reeves, & Knous, 2007). Conversely, older adults who have age-related sarcopenia and relatively higher %BF would have a low or normal BMI (Frankenfield et al., 2001). Because of this, %BF may be a more appropriate indicator of disease risk for specific subsets of the population. Ode, Pivarnik, Reeves, and Knous (2007) maintain that BMI for college-aged athletes is a poor indicator of %BF, and encourage the use of separate BMI cut points for this population. Other research on Asian populations (Blew et al., 2002; Goh et al., 2004) and postmenopausal women (Blew et al., 2002) also indicates that BMI is not representative of %BF.

It is important to understand the relationship between BMI and %BF in mid-and-older adults, as cardiovascular disease risk increases after 40 years of age (Mensah & Brown, 2007). Likewise, fat deposition patterning is known to influence disease risk. Individuals with a higher concentration of adipose tissue around the waist are at an increased risk of developing cardiovascular disease (Klein et al., 2007). Consequently, the American College of Sports Medicine (ACSM) recommends using waist circumference, in addition to BMI, to assess disease risk (ACSM, 2010).

Thus, the use of BMI to indicate obesity status and/or predict disease risk is a concern for several reasons. First, athletes tend to have a higher ratio of muscle mass to fat mass, and because muscle weighs more than fat, BMI may inaccurately predict disease risk in this group. In addition, health insurance premiums are influenced by BMI (ehealth, 2010). Depending on the insurance plan, an individual with a BMI greater than

25 kg·m^{-2} could pay a higher premium due to increased disease risk. Lastly, older active adults may have a higher BMI and charged additional fees when, in fact, they are at less risk for disease than their sedentary counterparts. Therefore, it is important to identify the true relationship between %BF and BMI in older, physically active individuals, and determine the appropriate BMI cut points that more accurately correspond to %BF in this subgroup. No research to date has studied the relationship between %BF and BMI in masters athletes. Determining these cut points could lead to more accurate risk stratification, and aid those who wrongfully pay higher health insurance premiums that were based solely on BMI. Therefore, the purposes of this study are to:

1. Describe the relationship between BMI and %BF in masters athletes, ages 45-65 years.

2. Determine the accuracy of the BMI category of overweight for masters athletes.

3. Analyze the relationship between waist circumference and BMI in masters athletes.

Hypotheses

1. Masters athletes will have a lower %BF and waist circumference for a given BMI of 25 kg·m^{-2} or higher, compared to the general population.

2. Body Mass Index will over-estimate disease risk for masters athletes.

Null Hypotheses

1. Masters athletes will have the same %BF and waist circumference for a given BMI of 25 kg·m^{-2} or higher, compared to the general population.

2. Body Mass Index will accurately estimate disease risk for masters athletes.

Assumptions of the Study

For the purpose of this study, the following assumptions are:

1. Residual lung volume measurement will be accurate.
2. When performing hydrostatic weighing, participants will exhale to residual volume.
3. Participants will be representative of masters athletes 45-65 years old.

Definition of Terms

The following terms are operationally defined for this investigation:

1. Hydrostatic densitometry: A testing method of determining body composition using Archimedes Principle of displacement. Hydrostatic weighing is considered the gold standard of body composition analysis.

2. Body Mass Index (BMI): Also known as Quetelet's index, BMI is the ratio of weight to height calculated by dividing weight in kilograms (kg) by $height^2$ in meters (m). It is used to indicate disease risk and estimate body fatness.

3. Residual Lung Volume: The volume of air remaining in the lungs after maximum exhalation.

4. Body Density: Body mass divided by body volume.

5. Percent body fat (%BF): Fat weight divided by body weight. Used to determine health and disease risk.

6. Masters athletes: An individual who competes in sporting events and/or races and is between 45-65 years old.

Delimitations

The delimitations of this study are as follows:

1. Participants are male and female competitive athletes, aged 45-65 years.
2. Participants recruited for this study will either have competed or are training to compete in a race within one month of the test date for this study.
3. Participants will be recruited from the Ithaca and the Greater Binghamton area.
4. Participants will be cyclists, runners, swimmers, or triathletes.

Limitations

The limitations of this study are as follows:

1. Results of this study may not be generalizable to those under the age of 45 or over the age of 65 years.
2. This study may not be generalizable to athletes who have not or will not compete in a race within the previous or upcoming month.
3. This study may not be generalizable to masters athletes in a location other than Ithaca or the Greater Binghamton area.
4. This study may not be generalizable to masters athletes in sports other than swimming, biking, running, or triathlons.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

This review outlines a brief history of BMI, its original purpose, the assumptions inherent in the BMI measurement, and the accuracy of BMI at predicting disease risk. This review will also discuss literature on certain subpopulations in which BMI has low sensitivity and specificity. Finally, the ways in which BMI classification may influence health insurance premiums in adult populations will be discussed.

Brief History of BMI

Body Mass Index was created in the early 1800s by Belgian mathematician Adolphe Quetelet. Quetelet was studying the association between height and weight in Belgian males, and while he did not find a significant correlation between height and weight, he did find a relationship between weight divided by the square of height. For example, Quetelet noted that individuals 10% taller than average were not 10 but 21% heavier. It is important to note that Quetelet's data collection was not for determining disease risk, but rather he was attempting to anthropometrically quantify the "average" man (Quetelet, 1842). Quetelet's equation had little impact on the medical community until the late 20th and early 21st centuries, when medical research was beginning to recognize the link between increased adiposity, mortality and development of diabetes, hypertension, and cardiovascular disease (Kuczmarski & Flegal, 2000). While increased adiposity was recognized as a contributor to mortality and comorbidities, the relationship between the two was unclear. In 1972, physiology professor and researcher, Ancel Keys, analyzed height, weight, and body fat percentage of 7,424 men and compared them to three different proposed equations to correlate %BF with height and weight measurements. The results indicated that the Quetelet index ($kg.m^{-2}$) was most highly related to %BF, height and weight, with a correlation of $r = 0.80$ (Keys, Fidanza, Karvonen, Kimura, Taylor, & Henry, 1972).

After publishing their research, Keys et al. (1972) renamed the Quetelet Index to Body Mass Index, and this measurement quickly gained traction in the scientific community. While this study was useful in determining body size measures that correlated with %BF, the authors warned about the use of this equation on an individual basis. In particular, they explained that gender and age were not accounted for in this equation, which could impact the health status of the individual (a male and female could have the same BMI but different %BF). Unfortunately, due to the ease of use, BMI is still widely used today as a predictor of body fatness and disease risk. Current research suggests that further research is needed to more clearly elucidate the effects of age, gender, and ethnicity on BMI as an indicator of body fatness (Blew et al., 2002; Dudeja et al., 2001; Goh et al., 2004).

Assumptions of BMI

Body Mass Index is an indicator of body fatness and is used to determine the disease risk at both the population and individual level via the trait relationship between fatness and disease. A major assumption of this measurement is that as BMI increases, there is a direct increase in body fatness. In essence, those with a high BMI should theoretically also have a high %BF. Considering that there has been a steady increase in body fatness over the years (approximately 60% of the United States is overweight or obese); (CDC, 2012), and an increase in adiposity has been linked to many chronic diseases such as atherosclerosis and diabetes (Ogden et al., 2004), it is crucial for physicians to be able to rapidly measure and interpret anthropometric data and create a plan of action (Jeffreys et al., 2003). While directly measuring %BF through densitometry or dual x-ray absorptiometry (DXA) would be the best course of action, BMI is quick and convenient. This convenience is most likely the reason BMI is still utilized so widely today, even though there are many limitations. Regardless, BMI is one of the most widely used disease risk tools available, and many studies have attempted to link %BF with BMI classifications. One study by Gallagher et al. (2000) compared BMI $\leq$35 kg·m^{-2} and %BF measures in 1,625 adults in order to determine %BF ranges that correspond to BMI categories. Gallagher et al. indicated that their participants were selected out of convenience, however, and may not be representative of the entire exercising, went through recent weight change, or were suffering from illness, which further limited the results. Despite these limitations, this study was the first to find healthy %BF ranges based on BMI limits for underweight ($<$18.5 kg·m$^{-2)}$, overweight ($\geq$25 kg·m^{-2}), and obese ($\geq$30 kg·m^{-2}), with further delineations between gender, age, and ethnicity.

<u>Limitations of BMI</u>

The degree of relationship between BMI and %BF varies, not only with gender, age, and ethnicity, but also with fitness level. Frankenfield et al. (2001) reported that 30% of men and 46% of women had average BMI measurements, but were obese by %BF measures. Similarly, BMI was reported to be 55% sensitive in men, but only 27% sensitive in women in determining overfatness (Hortobagyi, Israel, & O'Brian, 1994).

This suggests that men and especially women can be categorized as normal risk by BMI, but are overfat by %BF measures. It is apparent that using BMI as an indicator of disease risk or %BF can be misleading. In fact, false negative results were found for 41% of men and 32% of women in a sample of 4,723 subjects. (Deurenberg, Chew, Tan, Van, & Staveren, 2001). Further, 8% of men and 7% of women were classified as obese using the standard BMI cut points established by the World Health Organization. This is concerning because individuals who are at risk for developing cardiovascular and metabolic disease may not be identified as such. Others report wide variations between %BF measured by densitometry and BMI cut points (Smalley, Kneer, Zebulon, Kendrick, Colliver, & Owen, 1990), and the authors cautioned readers about the limited ability of BMI to indicate overweight or obesity on the individual level.

Current BMI cut points for overweight (25 $kg \cdot m^{-2}$), and obese (30 $kg \cdot m^{-2}$) (WHO, 2012) do not account for effects of ethnicity, age, or gender on BMI. Dudeja et al. (2001), indicates that BMI does not accurately predict overweight or obesity in Asian Indians living in Northern India. Using receiver operator characteristic (ROC) curves, Dudeja et al. determined optimal cut points for this population that minimized false negative and maximized true positive BMI classification results. The authors reported that an adjusted BMI of 21.5 $kg \cdot m^{-2}$ for males and 19.0 $kg \cdot m^{-2}$ for females yielded the highest sensitivity and specificity when determining a normal BMI and %BF for this population. Others amended BMI to strengthen the relationship of BMI and %BF for specific populations. Goh et al. (2004) altered BMI from 30 $kg \cdot m^{-2}$ to 27 $kg \cdot m^{-2}$ for men and 25 $kg \cdot m^{-2}$ for women, which increased the sensitivity and specificity for Asian populations from 6.7% and 13.4% to 46.7% and 60.8%, respectively. Further, Blew et al. (2004) indicated that a change in BMI cut points from 30 $kg \cdot m^{-2}$ to 25 $kg \cdot m^{-2}$ may be superior for diagnosing obesity in postmenopausal women.

Evidence indicates that Body Mass Index is not sufficient to define obesity within specific populations (Blew et al., 2004; Dudeja et al., 2001; Goh et al., 2004). Standard BMI cut points appear to misclassify athletes as well (Ode, Pivarnik, Reeves & Knous, 2007). Athletes typically have a greater muscle to fat ratio than their sedentary counterparts. Muscle weighs more than fat per unit volume, therefore competitive athletes are oftentimes mislabeled as overweight or obese by BMI standards. Often, athletes have lower %BF than sedentary individuals who are matched for BMI standards. Body type and sport training can affect BMI differently due to different performance demands (Nevill, Stewart, Olds, & Holder, 2005). The performance demands and safety factors for a football lineman require a higher BMI than a marathoner. With football, the athlete needs to have high body and muscle mass which contributes to a high BMI. Conversely, the performance demands of endurance sports require lower body mass to improve performance economy and results in a relatively lower BMI (Kong & Heer, 2008). Distribution of muscle and fat may be affected by sport. For example, Nevill et al. (2004) noted that strength and speed-trained athletes have significantly lower sum of skinfold measurements compared to inactive control groups after matching for BMI. This suggests that BMI is inaccurate as a predictor of %BF for an athlete. Furthermore, Nevill et al. suggest that skinfold and circumference measurements may be a more accurate indicator of disease risk than BMI in athletic populations. Similarly, Ode et al. (2007) found that a BMI of greater than 25 $kg \cdot m^{-2}$ is not an accurate predictor of increased adiposity in college-aged athletes and non-athletes. Due to relatively higher muscle mass, college-aged athletes are oftentimes mislabeled as overweight or obese. This suggests that separate cut points be established (27.9 $kg \cdot m^{-2}$ for males and 27.7 $kg \cdot m^{-2}$ for females) for college-aged athletes to optimize sensitivity and specificity of BMI (Ode et al., 2006).

It is clear that the relationship between BMI and %BF in college-aged athletes is not consistent with that of the general population. It is also clear that increased age has an effect on this relationship. For these reasons, it is plausible to also examine the BMI-%BF relationship in masters athletes. A masters athlete is an individual over the age of 40 who competes in masters competitions. Considering the increased risk for developing atherosclerosis and other chronic diseases with age, it is especially important to understand how BMI relates to disease risk in masters athletes (Jeffreys et al., 2003). Walsh et al. (2011) found a BMI of athletes studied over the age of 40 (n = 535) had a BMI of less than 30 $kg.m^{-2}$, but that 34% of rugby players in their study (n = 21) were classified as obese. Masters athletes used in this study were sampled from soccer, rugby, and touch football. Walsh et al. (2011) also found that masters athletes had a lower BMI than the general population, suggesting activity in sport aids in modulating excess adiposity.

Another study by Walsh et al. (2011) reported a small positive correlation between age and BMI in the general population (n = 12,346; r = 0.06, p = 0.001), but that this correlation was not seen in masters athletes (n = 6,071: r = -0.04, p = 0.003). Furthermore, the same survey by Walsh et al. (2011) of 6,071 athletes, ages 25 to 91 years revealed lower BMI's in older athletes compared to the general population. Limitations with both studies include the use of self-reported height and weight measurements. Height and weight was recalled by the subjects and not measured directly by the researchers. To contend with this limitation, large sample sizes of 535 and 6,071 subjects were used.

BMI and Lifestyle

Due to variations in ethnicity, gender, age, and distribution of body fat, BMI does not does not accurately predict disease risk of an individual. Ease of measurement, however, results in a wide use of BMI by the medical community to estimate disease risk. Additionally, BMI is often used by health insurance companies to estimate disease risk, and determine health insurance premiums. According to eHealth, a health insurance company that provides health insurance for over two million Americans, those who fall into the obese category determined by BMI, pay an average of 22.8% more per month than those in the normal category (eHealth, 2012). On average, an individual with a BMI between 18.5 and 24.99 pays $164 per month, whereas a person with a BMI between 25 and 29.99 pays $185 per month. Those who fall into the obese category ($\geq$30 $kg \cdot m^{-2}$) pay an average of $201 per month. It is not uncommon for an athlete to fall into an overweight or obese category, and because BMI often mislabels disease risk in this demographic, it is possible for many athletes to be charged higher health insurance premiums when they are at lower risk for disease than their BMI-matched sedentary counterparts.

While BMI is the preferred method to assess disease risk for some privatized health insurance companies, this use is not universal. According to the Army Weight Control Program (2012), new recruits are assessed for military readiness using height, weight, and waist girth. If a new recruit exceeds the maximum weight for height requirement, waist circumference measurements is used to estimate disease risk. Neither the U.S. Marines nor the U.S. Air Force use BMI to determine disease risk and military readiness.

Summary

Body Mass Index is used frequently to assess disease risk at both individual and population levels. However, for individuals, research reveals that the relationships between BMI, disease risk, and body fatness vary by age, gender, and ethnicity. Since the BMI measure does not account for age, gender, or ethnicity, the use of BMI to predict disease risk should be done so with caution. Among others, older adults and athletes are at risk for misclassification of BMI and/or body fatness, which could ultimately result in inflated health care costs and possibly even erroneous health care decisions.

CHAPTER 3

METHODS

The purpose of this study was to examine the relationship between BMI and %BF in masters athletes. This chapter outlines the methodology and procedures of the study. The following sections are as follows; (a) selection of participants, (b) study design, (c) measurement and procedures, and (d) statistical analysis.

Selection of Participants

After approval by the Ithaca College Human Subjects Research Committee, 35 (N_{male} = 24, N_{female} = 11) masters athletes aged 40-73yrs (M = 53.80, SD = 7.41) were recruited from various triathlon and running communities throughout Ithaca, Binghamton, and Syracuse, NY. Height, weight, waist circumference, BMI, %BF, and activity level were recorded during a one hour session. Participants were recruited through fliers and advertisements placed on campus, as well as through the Finger Lakes running and triathlon clubs. Interested participants were instructed to contact the researcher via contact information provided on the flier. Participation was voluntary. Only participants who had completed a race within one month of testing were included in the study. Limb amputees were excluded from participation due to the inability to accurately measure body composition. All participants read and signed the informed consent (Appendix A).

Study Design

Participants completed one day of testing that took one hour. Upon arrival, the participants were asked to complete a brief questionnaire about training history

(Appendix B). Following the questionnaire, height, weight, waist circumference, and residual volume were measured, followed by hydrostatic densitometry to determine underwater weight.

Measurements/Procedures

Anthropometry

Height was measured with a calibrated wall stadiometer to the nearest 0.10 cm. Weight was measured to the nearest 0.01 kg on a calibrated, eye level, medical physician's scale. Waist circumference was measured to the nearest 0.10 cm by using a Lufkin woven tape at the narrowest circumference of the torso between the umbilicus and the xiphoid process. Body Mass Index was calculated as weight (kg) / height^2 (m). Disease risk was determined using the BMI risk stratification table (p.63) and the Bray (Bray, 2004) waist circumference table (p.66) located in the ACSM's Guidelines for Exercise Testing and Prescription reference manual. (ACSM, 2010).

Residual Lung Volume

Residual lung volume (RLV) was measured immediately prior to underwater weighing (UWW) using closed-circuit oxygen dilution (Wilmore, 1969). The participant was seated in a posture that approximates the position during UWW. Two trials of RLV were performed within five minutes, and RLV was computed as the mean of the two trials. If the RLV measures varied by more than 10%, a third trial was measured, and trials 2 and 3 were averaged together.

Hydrostatic Densitometry

Hydrostatic densitometry was used to determine body density. A total of ten trials of UWW were completed in order to minimize trial variability. The average of the last three trials was used in order to calculate body volume. Underwater weight was measured on a hanging analog scale to the nearest 25 g. Body density (D) was determined through the following equation where UWW (Mw), residual volume (RV), water density (Dw), and body mass (Mb):

D = (Mb x Dw) / (Mb - Mw – RV x Dw) (ACSM, 2010, p.269),

Percent body fat was calculated with the Siri (1961), equation:

Percent Fat = [(495 / Body Density) -450] * 100

Lean Body Mass (LBM) was calculated as (ACSM, 2010, p.269):

LBM = Mb – (Mb x %BF)

Statistical Analysis

Data was analyzed using independent samples *t*-tests to compare BMI, weight, height, and waist girth between the general population and participants in this study. General population comparison data was acquired from the CDC Vital Health and Statistics study, which collected anthropometric measurements on 20,015 males and females between birth and 65+ years of age (CDC, 2012). Variables analyzed were %BF and BMI. Body Mass Index and %BF were also compared to the current BMI and %BF standards using chi-squared analysis (χ^2) for goodness of fit. Participants were classified into four groups: (1) overweight and overfat (TP); (2) overweight and normal fat (FP); (3) normal weight and overfat (FN); and (4) normal weight and normal fat (TN). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated to determine the accuracy of BMI to estimate overfatness. Sensitivity was calculated as the ratio of overfat individuals who were classified as overweight according to BMI (TP/ (TP + FN)). Specificity was calculated as the ratio of normal fat individuals who were classified as normal weight (TN/ (TN + FP)). Positive predictive value was calculated as the proportion of individuals classified as overweight by BMI, who were actually overfat (TP/ (TP + FP)). Negative predictive value was calculated as the proportion of individuals classified as normal weight who were actually normal fat (TN/ (TN + FN)).

CHAPTER 4

RESULTS

The purposes of this study were to: (1) describe the relationship between BMI and %BF in masters athletes; (2) determine the accuracy of BMI to identify overweight masters athletes; and to (3) analyze the relationship between waist circumference and BMI in masters athletes. Appendix D contains raw data for all variables. This chapter includes the following; (a) description of participants, (b) comparison of height, weight, waist girth, and BMI between masters athletes and the general population, (c) the accuracy of BMI as an indicator of obesity, and (d) summary of results.

Description of Participants

Participant physical characteristics are reported in Table 1. Participants were between 40 and 73 years (*M* = 53.83, *SD* = 7.41). Mean height and weight for males was 179.8 cm (*SD* = 9.59) and 80.9 kg (*SD* = 15.16), respectively. Mean height and weight for females was 165.7 cm (*SD* = 5.61) and 60.91 kg (*SD* = 8.07), respectively.

Exercise characteristics are reported in Table 2. On average, participants exercised for 5.4 days (*SD* = 1.07) per week, for 57.9 (*SD* = 15.92) minutes per exercise session. Modes of exercise included running, biking, and swimming, tennis and resistance training. On average, participants had exercised at this frequency for 11.5 (*SD* = 1.85) months, and had participated in their sport for 13.0 (*SD* = 10.94) years. Exercise recommendations from the Center for Disease Control (CDC) indicate that adults between the ages of 18 and 65 years do at least 150 minutes of moderate intensity exercise, or 75 minutes of vigorous intensity exercise per week (CDC, 2012). Athletes in this study were almost two-fold more active than the CDC recommendations for exercise.

Table 1.

Physical Characteristics of Subjects (Mean ± *SD*, Range)

	Males (*n* = 24)	Females (*n* = 11)	Total (*N* = 35)
Age (yrs)	53.3 ± 7.42 40-67	55.0 ± 7.59 45-73	53.8 ± 7.41 40-73
Height (cm)	179.8 ± 9.59 79.4-159.2	165.7 ± 5.61 153.3-172.2	175.4 ± 10.77 153.3-201.6
Weight (kg)	80.9 ± 15.16 61.0-117.8	60.9 ± 8.07 51.4-71.8	74.6 ± 16.23 51.4-117.8
%BF	16.9 ± 5.06 8.0-27.6	22.7 ± 4.43 16.6-29.4	18.7 ± 5.53 8.0-29.4
BMI ($kg*m^{-2}$)	24.8 ± 3.10 19.8-30.8	22.2 ± 2.27 18.3-25.3	24.0 ± 3.10 18.3-30.8
Waist Girth (cm)	85.1 ± 7.64 71.4-104.5	73.2 ± 5.86 66.4-85.5	81.3 ± 9.00 66.4-104.5

Table 2.

Exercise Characteristics of Subjects (Mean ± *SD*, Range)

Subject		Days of Exercise/Week	Exercise Duration (min)	Exercise Frequency (mo)	Participation in Sport (yr)
Males	*M*	5.5	60.0	11.8	11.3
	SD	1.10	18.24	1.13	10.37
	Range	4.0-7.0	45.0-90.0	6.0-12.0	3.0-38.0
Females	*M*	5.4	53.2	10.9	17.0
	SD	1.03	7.83	2.77	11.7
	Range	4.0-7.0	45.0-60.0	3.0-12.0	2.5-38.0
Total	*M*	5.4	57.5	11.0	13.0
	SD	1.07	15.92	1.85	10.94
	Range	4.0-7.0	30.0-90.0	3.0-12.0	2.5-38.0

Comparison Between General Population and Masters Athletes

Independent samples *t*-tests were conducted to compare BMI, weight, height, and waist girth between the general population and participants in this study. General population data comparisons were sampled from the CDC Vital Health and Statistics study, which collected anthropometric measurements on 20,015 males and females between birth and 65+ years of age (CDC, 2012). There were no significant differences in weight (kg) between the general population (M = 83.2, SD = 9.52) and masters athletes (M = 74.62, SD = 16.23); $t(34)$ = 0.74, p = 0.47 or height (general population M = 168.4, SD = 9.79); masters athletes (M = 175.4, SD = 10.77; $t(34)$ = -0.89, p = 0.38). However, the general population had a larger waist circumference (*M* = 101.3, *SD* = 4.81) versus masters athletes (*M* = 81.3, *SD* = 9.00); $t(34) = 3.09$, $p = 0.004$. The general population also had a higher BMI (*M* = 29.1, *SD* = 0.09) compared to masters athletes (*M* = 24.0, *SD* = 3.10); $t(34) = 2.24$, $p = 0.03$. These data indicate that masters athletes have a lower BMI and smaller waist circumference compared to the general population.

A chi-squared analysis for goodness of fit was used to assess the sensitivity and specificity of BMI to indicate obesity status in masters athletes. The incidence of true positive (TP), false positive (FP), and true negative (TN) were compared between masters athletes and the general population. False negative (FN) was omitted from the analysis because FN did not occur in this sample. Total sensitivity and specificity values for the general population were obtained from a meta-analysis of BMI and measured %BF (Okorodudu, Jumean, Romero-Corral, Summers, Erwin, & Lopez-Jimenez, 2009). Okorodudu et al. (2009) compared the accuracy of estimated %BF based on BMI to actual measured %BF in the general population by compiling sensitivity and specificity from 25 articles, 32 different patient samples and 31,968 patients. Overall sensitivity and specificity for a BMI cut point of 25 $kg \cdot m^{-2}$ was 0.5 and 0.9, respectively, indicating that a BMI $\geq$ 25 $kg \cdot m^{2}$ failed to identify half of the participants with excess %BF. When compared to the sensitivity and specificity of masters athletes in the present study, masters athletes had significantly fewer TP ($z = -13.10$), significantly more FP ($z = 8.80$), and significantly more TN ($z = 5.10$), $\chi^2 = 38.23$ (2, $N = 35$), $p < .0005$. Results indicate that significantly fewer masters athletes are overweight and overfat in this sample compared to the general population. A 2X2 contingency table comparing %BF and BMI (Table 3) and Figure 1 further illustrate these data.

Table 3.

2X2 Contingency Table Comparing %BF and BMI

	Normal Weight *N* (%)	Overweight *N* (%)	Total *N* (%)
Normal Fat	TN 21 (64%)	FP 12 (36%)	33
Overfat	FN 0 (0%)	TP 2 (100%)	2
Total	21	14	35 (100%)

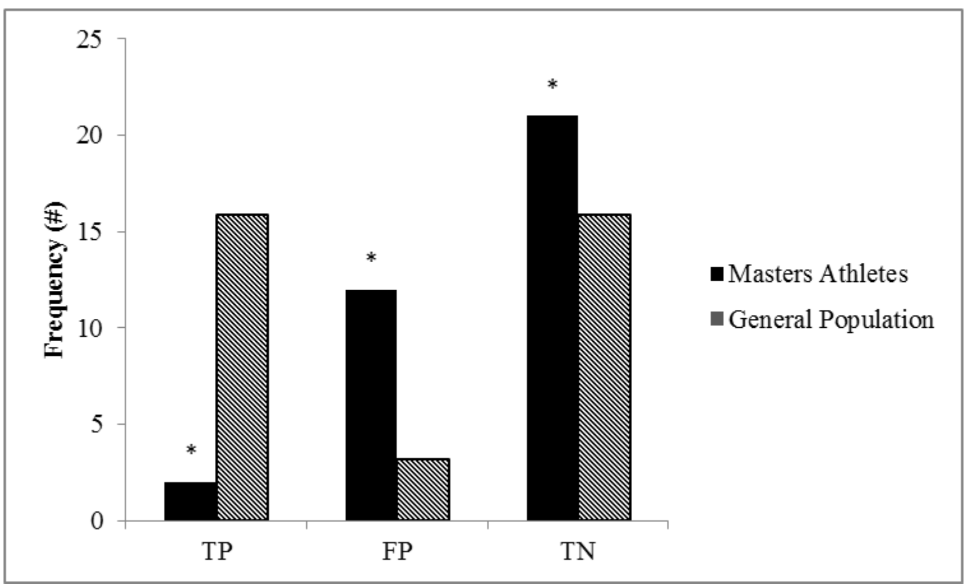

Figure 1. Comparison of BMI and %BF between masters athletes and the general population. Frequencies of True positive (TP), False positive (FP), and True negative (TN) results between masters athletes and the general population are noted. *$p < .0005$.

Similarly, χ^2 was used to compare %BF and to indicate obesity status. Data on the general population between 1994-2004 from the National Health and Nutrition Examination Survey (NHANES) indicates that 52.4% of the population was overweight according to waist circumference (Li, Ford, McGuire, & Mokdad, 2007). This percentage was used to compare waist circumference of masters athletes to the general population. Results indicate that more masters athletes had a normal waist circumference compared to the general population (z = 23.20). Results also indicate that significantly fewer masters athletes were categorized as overweight based on waist circumference (z = -23.20), χ^2 (1, N = 35) = 72.28. p < .0005. A 2X2 contingency table comparing WC and BMI (Table 4) and Figure 2 further illustrate these data.

Accuracy of BMI for Disease Risk Analysis

Gallagher et al. (2000) determined cut points for %BF based on data from 1,626 untrained males and females between 18-65 years of age. Height, weight, waist circumference, and %BF via dual x-ray absorptiometry were measured to determine the relationship between BMI cut points and %BF. A BMI of $\geq$ 25 $kg \cdot m^{-2}$ was used to classify individuals as overweight, and a %BF of 23.25% and 35.5%, respectively, were used to classify males and females as overfat. Participants were then classified into four groups: (1) overweight and overfat (TP); (2) overweight and normal fat (FP); (3) normal weight and overfat (FN); and (4) normal weight and normal fat (TN). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated to determine the accuracy of BMI to estimate overfatness.

Table 4.

2X2 Contingency Table Comparing Waist Circumference (WC) and BMI

	Normal Weight *N* (%) WC females <88 cm males <102 cm	Overweight *N* (%) WC females >88 cm males >102 cm	Total *N* (%)
Normal Fat BMI 18.5-24.9 kg/m^2	TN 34 (100%)	FP 0 (0%)	34
Overfat BMI 25.0- 29.9 kg/m^2	FN 0 (0%)	TP 1 (100%)	1
Total BMI 18.5-29.9 kg/m^2	34	1	*N* = 35 (100%)

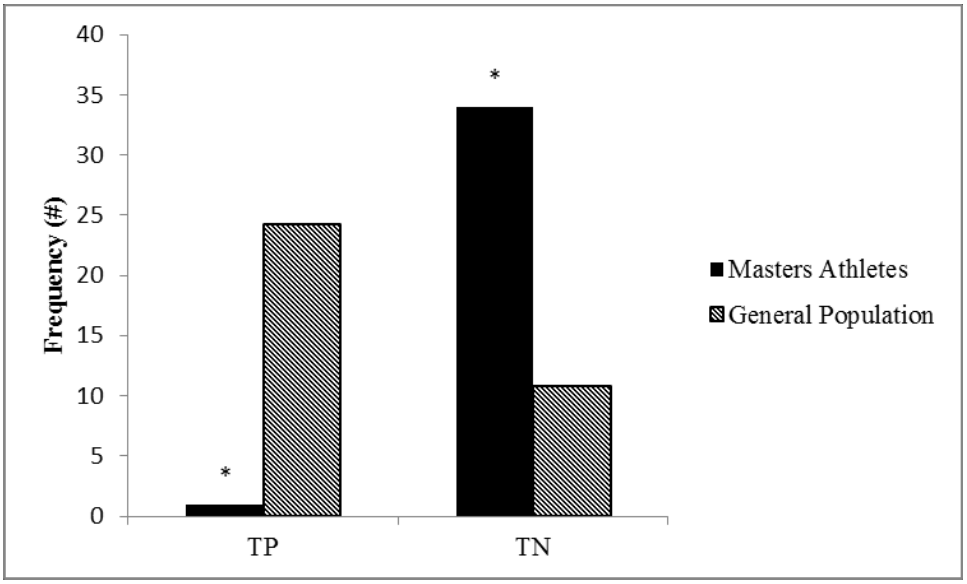

Figure 2. Comparison of BMI and waist circumference between masters athletes and the general population. Frequencies of True positive (TP) and True negative (TN) results between masters athletes and the general population are noted. *$p < .0005$.

Sensitivity was calculated as the ratio of overfat individuals who were classified as overweight according to BMI (TP/ (TP + FN)). Specificity was calculated as the ratio of normal fat individuals who were classified as normal weight (TN/ (TN + FP)). Positive predictive value was calculated as the proportion of individuals classified as overweight by BMI, who were actually overfat (TP/ (TP + FP)). Negative predictive value was calculated as the proportion of individuals classified as normal weight who were actually normal fat (TN/ (TN + FN)). Therefore, FN and FP decreased as the accuracy to estimate overfatness by BMI increased.

Sensitivity was calculated to be 100%, indicating that every individual who was classified as overweight (BMI), was truly overfat (%BF, n = 2). It is important to note that only two participants were classified into this category. NPV was also calculated to be 100%, indicating that for 100% of the cases, individuals classified as normal weight were, in fact, normal fat. Specificity was calculated to be 64% (*n* = 21), indicating that only 64% of the time, individuals who were classified as normal weight were truly normal fat. Positive predictive value was 14%, indicating that for all participants classified as overweight by BMI, only 14% (*n* = 2) were truly overfat. The apparent low relationship between BMI and %BF in masters athletes is further illustrated by the scatterplot shown in Figure 3 that reveals a non-significant correlation of $r(33) = 0.24$ ($p = 0.18$) between BMI and %BF.

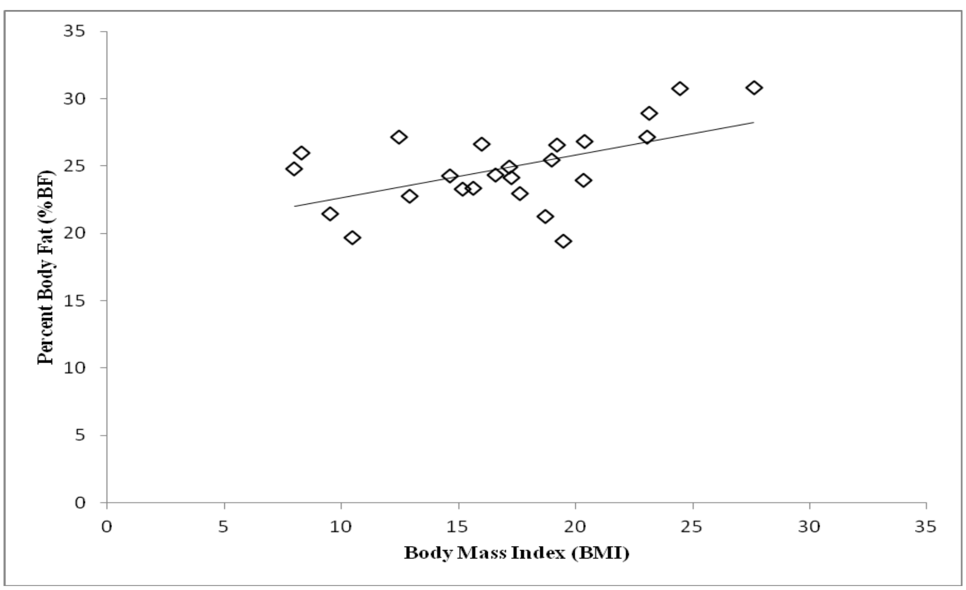

Figure 3. Relationship between BMI and %BF in the total sample population, $r(33) = 0.24$ ($p = 0.18$).

Summary

The relationship between BMI and %BF was evaluated in masters athletes, and BMI, height, weight, and waist circumference of the general population were compared to the sample population. Masters athletes had a significantly lower BMI and waist circumference compared to the general population.

The sensitivity of BMI to accurately categorize obesity status was calculated to be 100%, although it is important to note that only two participants were classified as overweight and overfat (TP). Specificity was calculated to be 64%. Positive Predictive value was calculated to be 14%, indicating a low probability that an individual identified as overweight by BMI was truly overfat. Negative Predictive Value (100%) was calculated as the proportion of normal weight individuals who were correctly identified as normal fat. A chi-squared analysis for goodness of fit to compare %BF and waist circumference between the general population and masters athletes revealed that masters athletes had smaller waist circumferences than the general population, and fewer TP. This means that masters athletes in this sample weighed less and were at lower risk for cardiovascular disease based on BMI compared to the general population. The number of TN and FP were also significantly higher than the general population, indicating that masters athletes in this sample were more often incorrectly labeled as overweight compared to the general population.

CHAPTER 5

DISCUSSION

Body Mass Index (BMI) is a tool used widely today as a simple indicator of body composition and disease risk. By dividing weight (kg), by height^2 (m), risk can be estimated for cardiovascular disease. A BMI of greater than 25 $kg \cdot m^{-2}$ is classified as overweight, whereas a BMI of greater than 30 $kg \cdot m^{-2}$ is classified as obese. Although BMI is simple and easy to use, it has been reported to be only 50% sensitive, and 90% specific in a meta-analysis of 31,968 participants (Okorodudu et al., 2009), indicating that many individuals who are classified as normal weight have elevated risk for disease. The purposes of this study were to; (1) describe the relationship between BMI and %BF in masters athletes, ages 45-65 years, (2) determine the accuracy of the BMI category of overweight for masters athletes, and (3) analyze the relationship between waist circumference and BMI in masters athletes. The main hypotheses for this study were; (1) masters athletes would have a lower %BF and waist circumference for a given BMI of 25 $kg \cdot m^{-2}$ or higher, compared to the general population, and (2) BMI over-estimates disease risk for masters athletes.

The primary findings of this study were; (1) masters athletes had significantly lower BMI and waist circumference compared to the general population, (2) compared to the general population, masters athletes were more often incorrectly labeled as overweight when they were not overfat , and (3) specificity and positive predictive value (PPV) were both low, indicating a low probability that a masters athlete classified as overweight by BMI was actually overfat based on percent body fat (%BF). A discussion of these results is contained in this chapter under the following sections: (1) Masters athletes vs. the general population, (2) Masters athletes and BMI, (3) Practical implications, and (4) Summary.

Masters Athletes vs. the General Population

Results from this study indicate that waist circumference and BMI were lower in masters athletes compared to the general population, but similar in height and weight. These results are in accordance with Walsh et al. (2011), who reported similar findings in masters athletes who had a significantly lower BMI compared to the general population. Body Mass Index of 6,071 masters athletes who competed in the Sydney World Masters Games were compared to the general population derived from the Australian National Health survey (N = 12,346). It should be noted that height and weight were self-reported and not directly measured, limiting the validity of this study.

In contrast, Ode et al. (2007), examined the relationship between BMI and %BF in college-aged athletes and non-athletes, and found that athletes were taller, heavier, and had a higher BMI compared to non-athletes. One possible explanation regarding the difference in findings between the present study and Ode et al. (2007) is aged-related sarcopenia in masters athletes. As the body ages, muscle cross-sectional area decreases resulting in less muscle mass and strength (Faulkner, Larkin, Claflin, & Brooks, 2007). Sarcopenia begins around age 30, and by 50 years of age muscle area can decline as much as 10% with inactivity (Faulkner et al., 2007). A decrease in muscle tissue innervation results in atrophy of muscle tissue, thus causing decreases in muscle cross-sectional area and subsequent decreases in muscle mass. This decrease in muscle mass causes a decrease in total body mass. Exercise has been shown to reduce the effects of age-related sarcopenia, mitigating rapid decline in muscle cross-sectional area and strength (Faulkner et al., 2007). Because masters athletes in the present study engaged in vigorous cardiovascular and resistance exercise, it is expected that muscle mass would be preserved. When compared to their age-matched sedentary counterparts, masters athletes had a lower BMI and waist circumference, which was partially unexpected, as it was hypothesized that masters athletes would have a greater muscle mass and thus have a greater BMI. One possible explanation for this would be that the goal of exercise later in life is oriented towards preservation and maintenance, rather than hypertrophy and growth. Conversely, as found by Ode et al. (2007), college-aged athletes, through rigorous training, may elicit relatively greater muscle growth and hypertrophy, thereby distinguishing them from their age-matched sedentary counterparts (having a higher BMI). In other words, it is easier to gain muscle cross-sectional area and strength while younger, and as an athlete ages, preservation and maintenance of muscle mass becomes the focus.

Another possible explanation for differences in BMI between the present study and Ode et al. (2007) would be the nature of the sport. Participants for this study were primarily endurance athletes (triathletes, swimmers, runners, and cyclists), whereas Ode et al. (2007) tested hockey players, football players, softball players, and basketball players. Nevill, Stewart, Olds, & Holder (2005) reported that different performance demands of sports resulted in different physiological adaptations, and therefore different body types. Masters athletes in our study competed in endurance sports. Physiological demands of endurance sports suggest a leaner physique to improve economy, sparing any excess weight to improve performance. In other words, hypertrophy of muscle tissue, development of type IIb muscle fibers, and increased body weight would place an endurance athlete at a disadvantage in endurance events. Therefore, the relatively lower BMI of masters athletes in the present study may be due to the nature of the sport in which they participated.

In the present study, waist circumference was lower in masters athletes compared to the general population. Results also indicate that masters athletes were two-fold more active than the CDC recommendations for exercise (CDC, 2012). Considering that approximately one third of Americans are sedentary and obese (CDC, 2012), and that athletes have lower BMI compared to the general population (Walsh et al., 2011; Walsh et al., 2011; Ode et al., 2007; Torstviet et al., 2012), the frequency of exercise appears to be inversely related to BMI and waist circumference. That is, those who meet or exceed the CDC recommendations for exercise appear to have a lower BMI and waist circumference than their age-matched sedentary counterparts.

BMI in Masters Athletes

Body Mass index is one of the most widely used tools to rapidly identify and stratify individuals for disease risk and body fatness. Due to non-invasiveness, ease of calculation, and rapid assessment, BMI is used to classify individuals as underweight, normal weight, overweight, and obese. Because BMI is used to estimate fatness status, and subsequently disease risk, accuracy of classification is highly relevant. Test accuracy is evaluated by sensitivity and specificity. Sensitivity is the ability of a test to identify a positive result, and specificity is the ability of a test to identify a negative result. Accuracy ranges from 0 to 100%, where 100% is highly accurate. Based on the results of the present study, sensitivity was calculated to be 100% and specificity was 64%. These results indicate that BMI was excellent at identifying masters athletes who were overweight and overfat. In other words, participants classified by BMI as overweight, were also overfat, as indicated by hydrostatic densitometry. It is important to note that only two participants were classified into this category, however. A larger sample size may challenge this sensitivity rating, as indicated in a meta-analysis by Okorodudu et al. (2009) that indicated an overall sensitivity of 50% and specificity of 90% in 31,968 participants aged 21-65 years. These data indicate that half of participants were incorrectly classified as overweight by BMI who had normal %BF.

Other researchers have presented similar findings with various sensitivities and specificities. Romero-Corral et al. (2008), for example, studied 13,601 participants between 20 and 79 years of age. Height, weight, %BF from bioelectrical impedance, and BMI were measured. They reported an average sensitivity of 42.5% and specificity of 97%, indicating a lower sensitivity than both Okorodudu et al. (2009), and the present study. This low sensitivity indicates that more than half of participants were incorrectly identified as obese. It is important to note however, that Romero-Corral et al. (2009) used bioelectrical impedance to determine %BF, which can be inaccurate depending on an individual’s hydration level. Jackson, Pollock, Graves, and Mahar (1988) measured %BF using bioelectrical impedance and hydrostatic densitometry on 68 participants. They reported a 4.6-6.4% standard error in bioelectrical impedance, and only a 2.5% standard error in hydrostatic densitometry, indicating that underwater weighing is a more accurate technique to analyze body composition than bioelectrical impedance. Furthermore, Shah, and Braverman (2012) studied height, weight, %BF via dual energy x-ray absorptiometry (DXA), and BMI on 1,393 participants (*M* = 51 yrs, *SD* = 14.2). They reported that 39% of individuals were misclassified as normal weight based on BMI, but obese by %BF (2012). This indicates that BMI can severely underestimate the prevalence of obesity compared to %BF measured by DXA.

Although BMI can oftentimes misclassify individuals as overweight or obese, another limitation of BMI is a false negative, or classification of “normal” weight when the individual is overfat. Specificity was 64% in the present study, indicating that 64% of the time, individuals classified as normal weight were, in fact, normal fat. A false negative BMI is of concern as a prognosticator of cardiovascular disease risk. An individual with a normal BMI may not take steps to attenuate disease risk factors, whereas one with a BMI that indicates overfatness might take steps to reduce risk factors.

Gallagher et al. (2000) measured BMI by sampling 1,626 adults from three countries to compare BMI and %BF. They reported that specificity is a more important test statistic than sensitivity due to the fact that many people can be classified as normal risk, when in fact they are at an elevated risk for cardiovascular disease. Gallagher et al. (2000) cautioned that older adults and older athletes are particularly at risk for false negative results due to age-related sarcopenia. Expressed differently, an older athlete or individual may have a normal BMI and may appear normal weight, but due to sarcopenia, a decrease in muscle tissue and an increase in adipose tissue can result in an increased adiposity with an unchanged BMI. This increased adiposity is correlated with cardiovascular disease (CDC, 2012). We did not report any false negative results in our study, although it is likely that false negative results would be seen with a larger sample size.

Researchers have attempted to improve sensitivity and specificity of fatness estimation of a sample by altering BMI cut points. Using Receiver Operator Characteristic (ROC) curves, sensitivity and specificity are plotted to determine the optimal BMI cut point for a sample. Ode et al. (2007) utilized ROC curves and reported that by changing the BMI cut point of 25 $kg \cdot m^{-2}$ to 27.9 $kg \cdot m^{-2}$, sensitivity improved from 27% to 92%, and specificity improved from 27% to 77% in male athletes. Romero-Corral et al. (2008) reported a 20% increase in sensitivity and specificity by using ROC curves and changing the BMI cut point from 25 $kg \cdot m^{-2}$ to 30 $kg \cdot m^{-2}$. Rahman and Berenson (2010) also used ROC curves to determine the ideal BMI cut point in 555 white, African-American, and Hispanic women, aged 20-33 years. Using the traditional cut point of 25 $kg \cdot m^{-2}$ sensitivity and specificity were 57.7% and 98.5%, respectively. Using ROC curves, BMI cut points were changed to 25.5 $kg \cdot m^{-2}$ for whites, 28.7 $kg \cdot m^{-2}$ for Hispanics, and 26.2 $kg \cdot m^{-2}$ for African-Americans, and sensitivity and specificity rose to 57.7% and 83.4%, respectively. These data suggest that BMI is a poor indicator of disease risk, as BMI does not account for body composition. Given evidence that BMI is of limited value to assess a wide variety of individuals, alterations to cut points should be made to increase test accuracy for various races and ethnicities.

Practical Implications

The purposes of this study were to describe the relationship between BMI and %BF in masters athletes (45-65 years), determine the accuracy of the BMI category of overweight for masters athletes, and to analyze the relationship between waist circumference and BMI in masters athletes. Body Mass Index has been shown to lack accuracy for use in women, various ethnicities, and athletes. However, no study has analyzed the accuracy of BMI to classify masters athletes as overweight or obese. Because cardiovascular disease risk increases after the age of 40 (Mensah & Brown, 2007), it is especially important to use an effective indicator of disease risk. Understanding that BMI is only 64% specific in masters athletes allows older athletic individuals to more fully explore other indicators of disease risk even when classified as normal by BMI standards. This study further reveals the flaws in using BMI as a sole indicator of disease that should be considered by those who predict disease risk for various reasons, such as determining healthcare premiums (ehealth, 2012). In these cases, BMI in conjunction with other assessment tools, would more accurately assess an individual's health and disease risk status.

Summary

Masters athletes in this study had significantly lower waist circumference and BMI compared to the general population. In this sample, BMI was 100% sensitive and 64% specific as an indicator of body fatness. This means that individuals in this study classified as overweight were truly overfat, and only 64% of individuals classified as normal weight were normal fat. Previous research on masters athletes indicate that masters athletes have a lower BMI than their sedentary counterparts, however, college-aged athletes have a higher BMI and weight compared to their aged-matched sedentary counterparts. This could be due to muscle hypertrophy and growth in young adult athletes, and age related sarcopenia in masters athletes. Use of ROC curves to more specifically ascertain cut points for greater sensitivity and specificity should be investigated in the masters athlete population, and could have important implications for more accurately prognosticating disease risk.

CHAPTER 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Due to ease of use and rapid measurement, BMI is a widely used tool to estimate body fatness and disease risk of an individual. Although BMI is used frequently, it is limited in the sense that it does not account for body composition, but is based only on height and weight. This limitation has had profound effects on elderly, women, various ethnicities, and athletes, as BMI has limited specificity to identify disease risk in these groups. Because cardiovascular disease risk increases after 40 years of age, it is especially important to have an effective estimation of disease risk, as such, this study: (1) described the relationship between BMI and %BF in masters athletes (N = 35, n_{male} = 24, n_{female} = 11) between 40-73 years; (2) determined the accuracy of the BMI category of overweight for masters athletes; and (3) analyzed the relationship between waist circumference and BMI in masters athletes.

Results indicated that masters athletes had a significantly lower BMI and waist circumference compared to the general population. Results from a chi-squared analysis for goodness of fit indicated that for the cut point of 25 $kg \cdot m^{-2}$, BMI was 100% sensitive and 64% specific, with a positive predictive value of 14%. Low specificity and positive predictive value indicate a low probability that a masters athlete classified as overweight by BMI was actually overfat by %BF.

Conclusions

The results of this study yielded the following conclusions:

1. Masters athletes had significantly lower BMI and smaller waist circumference compared to the general population,

2. Compared to the general population, more often masters athletes were identified by BMI as overweight, but were not overfat based on %BF.

3. Specificity and positive predictive value (PPV) of BMI were both low, indicating a low probability that a masters athlete classified as overweight by BMI was actually overfat by %BF.

Recommendations

The following are recommended for further study:

1. Use of ROC curves to more specifically ascertain cut points for greater sensitivity and specificity should be investigated in the masters athlete population.

2. Examine the relationship between BMI and %BF in masters athletes who compete in sports other than endurance based sports.

3. This study should be repeated with a larger sample size in order to ascertain a more representative sample and potential inclusion of false negative results.

4. Include more extensive measurements of disease risk to better relate BMI values to disease risk. The addition of total cholesterol (and HDL, LDL fractions), blood pressure, pulmonary function tests (PFT), and VO_2 max, for example.

5. Evaluate sex differences in the relationship between BMI and %BF in masters athletes.

6. Evaluate effects of race and ethnicity of masters athletes on accuracy of BMI as an indicator of disease risk.

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APPENDIX A

INFORMED CONSENT FORM

(Body Mass Index as a Predictor of Percent Fat in Competitive Masters athletes)

1. Purpose of the Study

Body Mass Index (BMI) is calculated by dividing body weight (in Kilograms) by one's height squared (in meters) and is used to classify obesity and risk of disease. A BMI classification between 25-29.9 kgm^{-2} is considered to be overweight and a BMI classification of greater than or equal to 30kgm^{-2} is considered obese. These measurements are used to predict estimated percent body fat, and falling into the overweight or obese category means that an individual is considered to have excess percent fat. Having excess body fat increases the risk for developing hypertension, heart disease, diabetes, and elevated cholesterol. Because BMI measurements do not analyze muscle, bone and tissue composition, and only measure total weight divided by height, it is possible for an individual to be classified as overweight or obese, without correlated percent fat. Athletes typically have increased muscle mass per height, which increases weight without an increase in body fat percentage. The purposes of this study are to, 1)describe the relationship between BMI and % fat in masters level competitive athletes, and, 2) determine the accuracy of the BMI category of overfatness($\geq$ 25kgm^{-2}) as a measure of excessive body fatness in masters level athletes.

2. Benefits of the Study

By participating in this study, you will have a very accurate measurement of your actual percent body fat. Hydrostatic weighing is considered a gold standard in the scientific community, and when performed correctly, is very accurate in predicting body fat percentages. You will also gain knowledge related to your personal BMI score, and how accurate this number is to your actual calculated percent fat.

The main benefit that this study brings to the scientific community is further knowledge about the accuracy of BMI in predicting body fat percentage. No evidence to date has analyzed the relationship between actual body fat percentage and predicted body fat percentage from BMI in master's level competitive athletes. Considering that some companies use BMI measurements as an indicator for increased health insurance costs, understanding the relationship between BMI, estimated percent fat, and actual percent fat in masters level athletes could lead to an alteration in how BMI is used for health insurance purposes.

3. What You Will Be Asked to Do

This study will be calculating your percent fat through hydrostatic weighing, your BMI through height and weight measurements, your vital capacity and your risk for cardiovascular disease through a waist circumference measurement.

Vital capacity is the maximal amount of air you can exhale. This measurement is needed to calculate your percent fat through hydrostatic weighing. To collect this, a noseclip will be placed on your nose, and you will be asked to maximally inhale, place your mouth on a mouthpiece connected to a spirometer, and exhale into the spirometer maximally 2-3 times.

The second component of measuring body fat percentage through hydrostatic weighing involves the use of an underwater weighing tank. You will be asked to wear a bathing suit, sit in the underwater weighing tank, and blow out all the air that you can exhale, bending slowly forward until the top of your head is underwater, and remaining motionless until the scale has settled. You will be asked to repeat this procedure 10 times to ensure an accurate number has been validated.

Initial__________

The total time to complete all of the measurements should be approximately 1 hour.
To be eligible for this study, you must engage in regular physical activity for at least 30 minutes on four or more days of the week, and have completed a race in the past, or plan to compete in a race (triathlon, pentathlon, cross country races, swimming, cycling, etc.).

4. Risks

Due to the minimal invasiveness of this study, the risks involved are minimal in nature. There is potential for falling injury when exiting or entering the hydrostatic weighing chamber, as water can accumulate outside of the tank and can become slippery. Steps to minimize extraneous water will be implemented to mitigate the potential for this to happen however. There is also a possible psychological distress that may occur with underwater weighing if you are anxious around water. In order to get an accurate measurement, we will ask you to exhale maximally and hold your breath underwater for 5-10 seconds. The tank is shallow enough to allow you to stand if you feel distressed about being underwater, and there will be multiple researchers trained in CPR and life support should anything go awry. We don't expect any complications to arise from this measurement, and hydrostatic weighing is considered a gold standard for its minimal risk to participants and accurate results.

5. Compensation for Injury

If you suffer an injury that requires any treatment or hospitalization as a direct result of this study, the cost for such care will be charged to you. If you have insurance, you may bill your insurance company. You will be responsible to pay all costs not covered by your insurance. Ithaca College will not pay for any care, lost wages, or provide other financial compensation.

6. If You Would Like More Information about the Study

Contact Mike FitzPatrick at either mfitzpa2@ithaca.edu, or by phone at 607-743-5791 if you have any questions or concerns regarding preparing, or what to expect, or any general questions you may have.

7. Withdraw from the Study

This study is completely voluntary. This means that you are free to withdraw from this study at any time without penalty, and you may omit answers on questionnaires that you feel uncomfortable answering.

8. How the Data will be Maintained in Confidence

The data collected and responses to questions will remain confidential. All data that is collected will remain in a folder and locked away from open view when not being used for data collection. Names will not be reported/ tied to data collected.

I have read the above and I understand its contents. I agree to participate in the study.

____

Print Name

____ ____________________

Signature Date

____ ____________________

Signature Date

Note: This information may be used for archival research in the future

APPENDIX B

PHYSICAL ACTIVITY AND HEALTH HISTORY QUESTIONNAIRE

Name__________________________ Date ________ DOB_ Age (yrs.)_________

Email __________________________ Local Address ____________________________

M / F (Circle)

What is your primary competitive sport? __________________________________

How many years have you participated in the sport (s) listed above?__________________

____

What kind of exercise do you do regularly? (check all that apply)	**About how frequently do you exercise?**	**For about how long do you exercise?**	**About how long have you exercised at this frequency?**
☐ walking ☐ running ☐ biking ☐ swimming ☐ weight training ☐ other ☐ I do not exercise	☐ 1x/wk ☐ 2x/wk ☐ 3x/wk ☐ 4x/wk ☐ 5x/wk ☐ 6x/wk ☐ 7x/wk or more	☐ < 15 min. ☐ 15-30 min. ☐ 30 – 45 min. ☐ 45 min. – 1 hr. ☐ 1-1.5 hrs. ☐ Over 1.5 hrs.	☐ less than 1 month ☐ 1-3 months ☐ 3-6 months ☐ 6-9 months ☐ 9-12 months ☐ over 1 year
Comments:			

FAMILY HISTORY

Check any medical problems your family has had, <u>and</u> the age at which the problems began:

Disease	Grandmother (Diagnosis Age)	Grandfather	Mother	Father	Sister	Brother
Type I Diabetes						
Type II Diabetes						
High Blood Pressure						
Heart Disease						
Cancer						

HISTORY OF MEDICAL CONDITIONS

Have <u>you</u> **ever** had any of the following conditions? (Check all that apply)

☐ Anemia (low iron blood) ☐ Asthma (wheezing) ☐ Diabetes (sugar)

☐ Heart Disease ☐ Cancer

☐ Tuberculosis (TB) ☐ Liver Trouble

☐ Pneumonia ☐ Rheumatic fever

☐ Stroke ☐ High Blood Pressure

☐ Skin problems ☐ Depression (feeling down or blue)

☐ Epilepsy (fits, seizures) ☐ Anxiety (nerves, panic attacks)

☐ Other____

Comments: ____

Please list if you know the following numbers:

Blood Glucose______Total Cholesterol_____Triglycerides________ HDL______LDL____

Are you taking any **prescription medicines**?

☐ Yes. Please list your medicines below

☐ No, I do not take any prescription medicines.

Name of medicine	**Amount / size of pill**
Example: Furosemide	20 mg

Do you take **over-the-counter medicines** regularly?

☐ Yes. Please list: ____

☐ None - I do not take any over-the-counter medicines regularly.

Have you **ever smoked cigarettes, cigars, used snuff, or chewed tobacco**?

☐ No

☐ Yes

a. When did you start?____

b. How much per week? ____

c. Have you quit?............................☐ No ☐ Yes, when______________

Do you drink **alcohol**?

☐ No ☐ Yes (How many drinks per week?) _________________

APPENDIX C

DATA COLLECTION SHEET

Name______________________ Date______________________________

Age________________________ DOB______________________________

Sport______________________ Comp. Date________________________

VITAL CAPACITY = ________ RESIDUAL VOLUME = ____________

	TRIAL 1	TRIAL 2	TRIAL 3	R
SV =				
N_2X =				
N_2I =				
N_2E =				
N_2F =				
RV =				

Dry Body Weight (KG): ____________________ Tare Weight (KG):____________

Water Temperature (F): ______________ Water density: (9G/ML):_______

Height (CM): ______________________ Waist Circumference (CM):____

BMI: _____________________________ Age: _______________________

UNDER WATER WEIGHT

1. ______________________________ **6.** ______________________________

2. ______________________________ **7.** ______________________________

3. ______________________________ **8.** ______________________________

4. ______________________________ **9.** ______________________________

5. ______________________________ **10.** ______________________________

Average Weight (3 trials): ______________ **Body Density: _________________________**

Percent Body Fat: ____________________

EQUATIONS

RV = [{(SV + 0.124) (N_2E – N_2X) / (N_2I – N_2F)} – DS] *BTPS

Wet Weight = Underwater weight – tare weight

%BF = [(4.570 / Db) – 4.142] * 100

Db = dry weight / [(dry weight – wet weight) / water density) – RV – 0.1]

APPENDIX D

RAW DATA TABLES

Male Anthropometric Data:

Name	Age	Wt (kg)	Ht (cm)	RV	%BF	BMI	Waist Circumference
DD	61	64.91	166.70	2.3	15.65	23.36	80.4
DK	46	64.55	159.21	1.82	18.96	25.47	80
SB	63	61.00	169.29	1.176	18.71	21.28	75.4
SE	55	82.36	196.01	3.14	9.54	21.44	83
CR	55	86.36	186.21	1.456	17.18	24.91	88
RO	63	80.09	183.01	2.63	20.33	23.92	86
WM	48	77.27	178.51	1.84	14.63	24.25	86.7
DB	53	71.36	171.20	1.69	16.57	24.35	82.5
AH	50	80.45	182.50	2.18	17.26	24.16	83.5
JM	64	73.14	178.51	2.49	17.6	22.95	85.5
WS	49	117.64	201.60	3.27	23.13	28.94	100

Male Anthropometric Data Continued:

Name	Age	Wt (kg)	Ht (cm)	RV	%BF	BMI	Waist Circumference (cm)
BT	41	117.82	195.50	2.12	27.62	30.83	104.5
JD	57	70.00	175.26	2.08	12.92	22.79	79.4
PM	51	86.36	179.40	2.6	20.36	26.83	91.44
JL	40	75.45	179.91	2.11	15.19	23.31	83.3
HE	67	61.14	177.50	2.59	19.46	19.4	73.4
DF	46	90.05	182.19	2.43	12.45	27.12	88.2
SP	56	82.27	176.10	2.1	19.21	26.53	88.5
MV	54	79.09	174.40	2.81	8.3	26	81
EB	47	98.18	190.09	1.708	23.05	27.17	87
BG	55	82.82	176.40	2.11	16	26.62	86.5
HC	51	85.91	186.06	3.59	7.98	24.82	84.3
GM	45	61.91	177.50	1.92	10.48	19.65	71.4
PK	62	91.55	172.49	1.92	24.46	30.77	95.7

Female Anthropometric Data:

Name	Age	Wt (kg)	Ht (cm)	RV	%BF	BMI	Waist Girth (cm)
MH	51	53.64	157.68	1.21	23.99	21.57	70
LF	47	59.95	164.01	1.77	20.86	22.29	69
MT	53	65.91	167.21	2.09	22.55	23.58	74.5
DB	53	71.36	171.20	1.69	16.57	24.35	75
CJ	73	53.64	153.29	2.44	27.91	22.82	75.7
AG	45	60.91	172.21	1.72	19.56	20.54	70
JG	55	55	166.19	1.89	22.95	19.91	68.5
JR	63	51.36	167.59	2.11	17.92	18.29	66.4
JM	55	71.82	168.40	1.92	29.4	25.33	79.8
LC	55	54.09	166.09	1.99	18.43	19.61	71
JM	55	71.82	168.40	1.92	29.4	25.33	85.5

Male Exercise Frequency:

Name	Sport	Exercise Frequency (days/wk)	Time Spent Exercising (min)	Frequency of Exercise (mo)	Total years in sport
DD	Tri	6	45	12	3
DK	Tri	4	45	12	3
SB	Tri	4	30	12	7
SE	Tri	7	90	12	14
CR	Cycling	6	90	12	5
RO	Cycling	7	60	12	10
WM	Swimming	5	60	12	6
DB	Cycling	5	60	12	12
AH	Cycling	7	60	12	4
JM	Running	5	45	12	38
WS	Tri	5	90	6	4

Male Exercise Frequency Continued:

Name	Sport	Exercise Frequency (days/wk)	Time Spent Exercising (min)	Frequency of Exercise (mo)	Total years in sport
BT	Tri	4	60	12	3
JD	Running	7	45	12	22
PM	Running	5	60	12	3
JL	Running	6	60	12	9
HE	Running	6	60	12	32
DF	Cycling	5	60	12	4
SP	Tri	7	90	12	25
MV	Tri	5	45	12	12
EB	Tri	5	90	12	4
BG	Swimming	7	60	12	10
HC	Tri	5	45	12	7
GM	Running	4	30	12	30
PK	Tri	4	60	12	3

Female Exercise Frequency:

Name	Sport	Exercise Frequency (days/wk)	Time Spent Exercising (min)	Frequency of Exercise (mo)	Total years in sport
MH	Tri	7	45	3	6
LF	Running	5	45	12	30
MT	Tri	6	60	9	7
DB	Tri	5	60	12	2.5
CJ	Tri	5	45	12	10
AG	Tri	5	60	12	10
JG	Running	4	60	12	20
JR	Running	7	60	12	30
JM	Tri	4	45	12	12
LC	Cycling	6	60	12	20
JM	Running	5	45	12	38