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Comparison of Body Composition Measures in Older Adult Males

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Comparison of Body Composition Measures
In Older Adult Males

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HONORS PROJECT

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LITERATURE REVIEW

As individuals age, there are several physical changes that occur. These changes include a decrease in height due to spinal compression, an increase in weight due to reduced metabolism changes and decreased physical activity, and loss of bone and muscle due to hormonal changes and physical inactivity. Additionally, older adults typically experience weight gain through the accumulation of harmful adipose tissue rather than an increase in muscle mass. In 2008, there were 1.46 billion adults worldwide who were classified as overweight, as determined by an analysis of 199 countries. Of these overweight adults, 502 million were classified as being obese (Wang, McPherson, Marsh, Gortmaker & Brown, 2011). This obesity epidemic is extremely important because obesity is directly related to negative health consequences such heart disease, stroke, type II diabetes, and some cancers; all of which can be debilitating and negatively impact quality of life (Mittal, Goyal, Dasude, Quazi, & Basak, 2011). Obesity also contributes significantly to annual medical costs, estimated at between 4 and 7% of the total health care bill in the United States (equivalent to roughly $75 billion in 2003) (Wang, McPherson, Marsh, Gortmaker & Brown, 2011). In the next two decades, a study predicts that, following historical tendencies, 8 million cases of diabetes, 6-8 million cases of coronary heart disease or stroke, and 500,000 cases of cancers will arise due to obesity-related complications (Wang, McPherson, Marsh, Gortmaker & Brown, 2011). Thus, the obesity epidemic has significant implications on health as well as economics.

In addition to the aforementioned body changes, many older adults also experience sarcopenia, loosely defined as the progressive deterioration and loss of muscle mass within the body, often accompanied with impaired muscle functioning and strength. This decline in muscle tissue can begin as early as the fourth decade of life (McIntosh, Smale & Vallis, 2013).

Sarcopenia can also be classified into two areas: primary or secondary. Primary sarcopenia is solely due to the normal aging process, whereas secondary sarcopenia also includes lifestyle variations, diseases, and nutritional factors that may additively contribute to the extent of sarcopenia in the individual (Cruz-Jentoft, 2013).

However, studies show widely variability in the prevalence of sarcopenia in older adults, likely due to the lack of a measurable clinical definition of sarcopenia. Conflicting data reports the prevalence of sarcopenia ranging from 6% (McIntosh, Smale & Vallis, 2013) to 55% (Krause, McIntosh & Vallis, 2012). Yet another study found the prevalence of sarcopenia in the 60-70 year old age group to be 5-13% and in the 80+ age group to be 11-50% (Cruz-Jentoft et. al., 2010). There is a push to create a clinical definition of sarcopenia based on two primary criteria: a loss of muscle mass and an associated loss of strength and functionality (Cruz-Jentoft et. al., 2010). A clinical protocol for the assessment of sarcopenia is important because sarcopenia is associated with decrease mobility, increased falls (and resulting bone fractures), difficulties performing activities of daily living (ADLs), disability, and more (Cruz-Jentoft et. al, 2010).

Thus, changes in body composition may include 1) increased fat mass alone, 2) decreased muscle mass alone, or 3) a combination of both increased fat mass and decreased muscle mass. With this range of possibilities, techniques to assess body composition become a vitally important means of assessing risk for health complications and diseases in the older population. The third of these listed options is prevalent in the elderly population and has been described as sarcopenic obesity (Cruz-Jentoft et. al, 2010). The fat gained in later life is typically intramuscular and visceral. This visceral and intramuscular fat is associated with an increase in obesity related diseases because it is concentrated around the internal organs and places added stress on their functioning. As the obesity epidemic continues, it is vital to keep track of levels of sarcopenia as well. Conservative estimates hypothesize that there will be over 200 million people who experience sarcopenia over the next 40 years (Cruz-Jentoft et. al, 2010). This can lead to significant and dramatic increases in health challenges and complications faced by older adults, stressing the need for methods to assess body composition.

BODY MASS INDEX (BMI)

Currently, the most commonly used tool to assess health risk is the body mass index (BMI). BMI is computed from one's weight in kilograms divided by their height in meters squared. On a population level, BMI is linked to health risks and complications associated with obesity as listed previously. The cutoffs for BMI, according to the Center for Disease Control's standards, are: less than 18.5 kg/m^2 (underweight), 18.5-24.9 kg/m^2 (normal), 25-29.9 kg/m^2 (overweight), and greater than 30 kg/m^2 (obese) (About BMI for Adults, 2011).

BMI's originally intended purpose was for population-based analysis, but due to the simplicity of this method, BMI gained popularity in individual diagnosis as well. However, BMI has faced much scrutiny, as it does not directly measure fat, but is merely a mathematical formula that is associated with body composition but in no way directly assesses it. Potential problems associated with BMI scores are that men tend to have higher BMIs than women and older adults tend to have higher BMIs than children and young adults (About BMI for Adults, 2011). Studies have shown that there was no correlation between BMI and either cardiovascular disease mortality or all-cause mortality, likely due to the fact that BMI does not reflect the amount of dangerous abdominal visceral fat (Hollander, Bemelmans & Groot, 2013). A systematic review of current literature discussed two significant reasons why BMI is not an appropriate predictor of mortality: it lacks the ability to discern between fat mass and fat free mass, and the height measurements may be unreliable due to shrinkage and vertebral collapse (Chang, Beason, Hunleth & Colditz, 2012). This same systematic review also found BMI to be a negative predictor of several health consequences including metabolic syndrome (Chang, Beason, Hunleth & Colditz, 2012).

RESEARCH PROBLEM

With many sources questioning the validity and usefulness of BMI, why is it still being utilized so prevalently? The main reason is due to its simplicity and its ability to assess and generalize large populations. However, there are many ways to assess body fat; either through anthropometric means such as waist circumference (WC) and sagittal abdominal diameter (SAD) or body compositional methodologies such as bioelectrical impedance activity (BIA) or air displacement plethysmography (ADP). This study seeks to compare the accuracy, relevancy, and appropriateness of some of these methods in order to justify the use of some methods in preference over others. The following sections detail some of the most well-known methodologies in assessing body composition and obesity.

WAIST CIRCUMFERENCE (WC)

Waist circumference (WC) is the simple measure of a subject's waist either at its narrowest point or at the umbilicus with a Gulick tape measure (Figure 1). WC is an important tool because it measures the human trunk. As we age, the locations of fat on the body change and tend to accumulate in the abdominal region. Due to this shift in body fat distribution from subcutaneous fat (under the skin) to visceral fat (around the internal organs), this study showed WC to be more relevant than other circumference measurements such as the arm or the calf (Krause, McIntosh & Vallis, 2012). This visceral fat is extremely dangerous to one's health, particularly for its impact on the internal organs in the abdomen such as the heart, liver, and kidneys.

Waist circumference classifies men as either at normal risk or at high risk for health complications. Men with a WC of over 102 centimeters (40 inches) are classified as high risk. In a study of 2080 participants, a decrease of WC of more than 3.1 centimeters was significantly associated with cardiovascular disease mortality and an increase in WC of between 3.1 and 6.9 centimeters was associated with an increased likelihood of all-cause mortality (Hollander, Bemelmans & Groot, 2013).

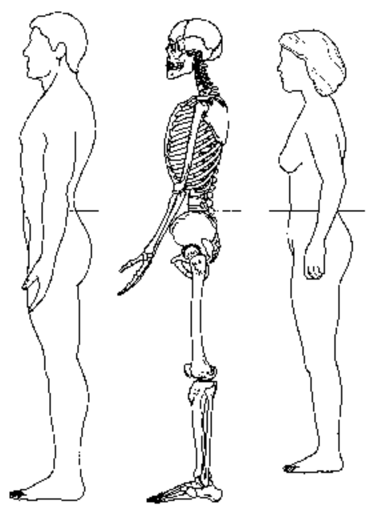

Figure 1. Measuring tape position for waist circumference. High disease risk is >102 cm (> 40 in) for men and > 88 cm (> 35 in) for women. Image from: http://www.nhlbi.nih.gov/guidelines/obesity/e_txtbk/txgd/4142.htm. Guidelines from: National Institutes of Health's Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: the Evidence Report (Obes Res. 1998; 6: (suppl 2): 51S–209S).

A 2012 systematic review by Chang, Beason, Hunleth & Colditz discussed the association between visceral fat accumulation and health consequences such as metabolic syndrome, inflammation, and dyslipidemia in which waist circumference has a positive association (Chang, Beason, Hunleth & Colditz, 2012). This same review of 2702 citations found waist circumference to overcome the obesity paradox better than BMI assessment. The obesity paradox is a phenomenon in which overweight and obese subjects actually have better survival outcomes than the normal weight category (even though due to their overweight/obesity they are more likely to face mortality-related diseases) (Chang, Beason, Hunleth & Colditz, 2012). Other studies also determined the link between waist circumference, type II diabetes, and metabolic syndrome (Duren, Sherwood, Czerwinski, Lee, Choh, Siervogel, & Chumlea, 2008).

A study of 2032 Chinese subjects compared waist circumference at specific BMI levels (of 25 and 30 kg/m^2) in the older population with those of a younger reference population (Woo, Ho, Yu & Sham, 2002). This study found that older adults at with the same BMI as younger adults had significantly larger measurements of waist circumference (approximately 6.0 cm) (Woo, Ho, Yu & Sham, 2002). Another study also compared BMI and WC in a 12 year longitudinal study of 1780 subjects over 65 years in age. This study showed that WC was associated with mortality in all older adults, with even stronger associations among individuals with congestive heart failure (CHF) (Testa, Cacciatore, Galizia, Della-Morte, Mazzella, Langellotto, Russo, Gargiulo, De Santis, Ferrara, Rengo & Abete, 2010). This study determined that each centimeter increase in WC was linked to a 2% increase in long-term mortality risk in those without CHF and a 5% increase in those with CHF. This study also concluded that WC helped to eliminate the obesity paradox in comparison to BMI (Testa et. Al, 2010).

SAGITTAL ABDOMEN DIAMETER (SAD)

Sagittal abdomen diameter (SAD) is very similar to WC, except that in SAD the subject is in a supine position rather than an upright standing position. (Figure 2). The importance in this change of positioning for measurement is so the subcutaneous fat will not slide to the sides of the waist as in the WC method (Pimentel, Moreto, Takahashi, Poreto-McLellan & Burini, 2011). This method has many of the same correlations as WC and additionally is more strongly associated with dyslipidemia and hyperglycemia (Pimentel, Moreto, Takahashi, Poreto-McLellan & Burini, 2011). Another study determined SAD to have stronger correlations in women than in men (Pimentel, Portero-McLellan, Maestá, Corrente & Burini, 2010). In a study of middle-aged adults, SD was shown to correlate strongly to a multitude of heart disease risk factors (Pimentel, Moreto, Takahashi, Poreto-McLellan & Burini, 2011). SAD can also be measured with a ruler or a caliper system which allow for easy measurement and reliability (Pimentel, Moreto, Takahashi, Poreto-McLellan & Burini, 2011). SAD results, measured with a sliding beam caliper have been shown to have good reproducibility and have been shown to be accurate in comparison to computer tomography scans (CT scans) (Öhrvall, Berglund & Vessby, 2000) (Parr & Haigh, 2006).

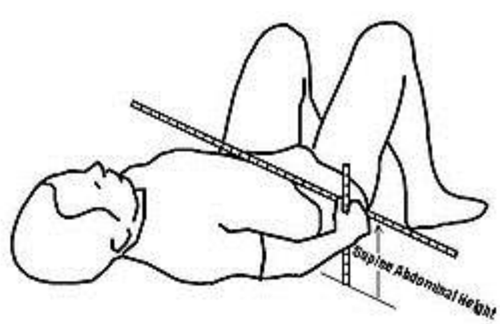

Figure 2. Sagittal abdomen diameter. Image from: http://www.absoluteastronomy.com/topics/Sagittal_Abdominal_Diameter,

BIOELECTRICAL IMPEDANCE ANALYSIS (BIA)

Bioelectrical impedance analysis (BIA) is a body composition test performed by sending electrical pulses through the body briefly (Figure 3). Different body tissues have variable electrical conductivity and thus different impedance (Mittal, Goyal, Dasude, Quazi, & Basak, 2011). Muscle and water have low impedance whereas adipose fat has high impedance (Mittal, Goyal, Dasude, Quazi, & Basak, 2011). Issues with accuracy in BIA come from the sensitivity of the test to water and electrolyte levels within the body (Krause, McIntosh & Vallis, 2012). Older adults tend to carry more water weight, which influences the effectiveness of this test.

Figure 3. Bioelectrical impedance analysis. Image from: http://www.medi-shop.gr/en/MedicalDevices/Body-fat-monitors/inbody-230.

Bioelectrical impedance analysis has been shown to be significantly more accurate at assessing body composition than BMI. In a study of 276 subjects from India, 3.9% of men and 5.7% of women were considered obese through BMI and 52.9% of men and 52.9% of women were considered obese through BIA (Mittal, Goyal, Dasude, Quazi, & Basak, 2011). BIA tends to be more efficient than anthropometric methods, because it is based on a two compartment model of distinguishing between fat mass and fat-free mass (Chang, Beason, Hunleth & Colditz, 2012). Another study shows that BIA, like BMI, can be useful in large groups of individuals, but that individual variance with BIA can be high (Duren, Sherwood, Czerwinski, Lee, Choh, Siervogel, & Chumlea, 2008).

AIR DISPLACEMENT PLETHYSMOGRAPHY (ADP)

Air displacement plethysmography (ADP) also uses the same two compartment model as BIA. ADP was created as an alternative to the "gold standard" of body composition methods: hydrodensitometry or "underwater weighing" (UWW). UWW had complications with compliance because of the taxing physical strain (submerging oneself underwater and exhaling subject's lungs to the greatest possible extent) that it can take on subjects, which is particularly relevant to testing with older adults (Alemán-Mateo, Romero, Macías Morales, Salazar, Triana & Valencia, 2004; Testa, Cacciatore, Galizia, Della-Morte, Mazzella, Langellotto, Russo, Gargiulo, De Santis, Ferrara, Rengo & Abete, 2010). ADP is less physically demanding and the process of assessment is quicker as a whole (Alemán-Mateo et. al., 2004). ADP uses the same formulas as UWW (e.g., Siri and Brozek) since they both are volumetric measures. Even though ADP appears to have several benefits over UWW, ADP does tend to slightly overestimate density, thus underestimating the percentage of body fat slightly (Collins & McCarthy, 2003). The test-retest variability in ADP is equal to about .8% body fat (Collins & McCarthy, 2003). This is in comparison to .99% body fat variability in UWW (Collins & McCarthy, 2003).

ADP is performed by utilizing BOD POD technology (Figure 4). The BOD POD is a two-chambered machine that controls for pressure (How does the BOD POD work? 2013). First, the subject is weighed on an extremely precise scale and then their volume is measured while sitting still within the BOD POD (How does the BOD POD work?, 2013). By taking both the weight and the volume of the subject, their density can be determined. The subject's lung capacity is important in volumetric measures, but predicted values according to Siri and Brozek are typically used depending on the population being tested (e.g., Siri for Caucasians and Brozek for African Americans) (How does the BOD POD work?, 2013).

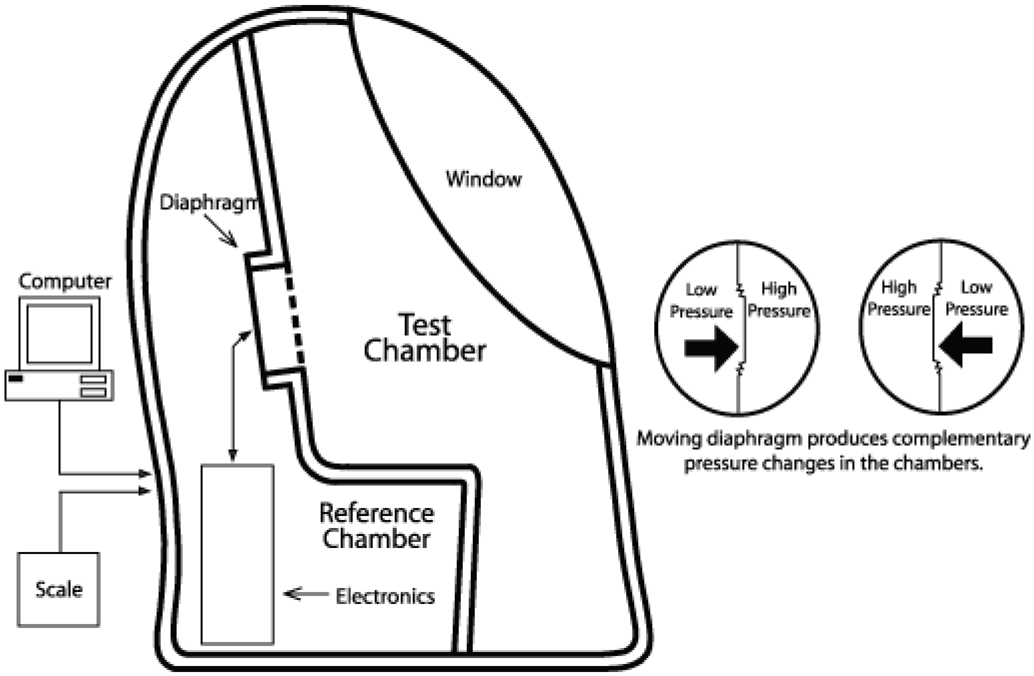

Figure 4. BOD POD technology used for Air Displacement Plethysmography. Image from How does the BOD POD work?. (2013). Retrieved December 11, 2013, from http://ybefit.byu.edu/Portals/88/Documents/How%20Does%20The%20BOD%20POD%20Work.pdf

In this study, we took measurements of body composition through each of these methods (i.e., BMI, WC, SAD, BIA, and ADP) and compared their accuracy to attempt to determine the best method for assessing obesity in the older adult population. The measuring of body composition and overweight/obesity is vitally important because we want to be able to properly identify those individuals that are overfat, due to the health risks they face. By continuing to rely upon BMI as the primary tool to assess obesity, a multitude of older adults may appear to be at a healthy and appropriate weight, while actually being overweight or obese. By utilizing some of these other techniques to assess body composition, practitioners can improve their patient's health outcomes (by being better aware and better suited to prevent negative disease outcomes associated with excess body fat and obesity). This improvement can also have financial benefits for insurance companies, taxpayers, and even the patients by being able to address risk for morbidities sooner and potentially reduce the amount of diseases and health-related consequences this population faces.

METHODOLOGY

In this study we performed BMI, WC, SAD, bioelectrical impedance analysis, and air displacement plethysmography (via BOD POD) assessments on older adult males, aged over 50. These males were recruited via Campus Updates, fliers on Bowling Green State University campus, and fliers distributed in the community. We expected to find ADP to be the most accurate method, as it is most similar to the gold standard of body composition methodologies (UWW). Prior to the study, we did not postulate as to which of the remaining methodologies would be most appropriate and accurate in comparison to ADP, due to the variability in water and electrolyte concentrations and the variability in body shape. However, it was expected that BMI would produce the least relevant and least appropriate results among all the techniques examined.

On a day of data collection, the tester arrived thirty minutes prior to the subject, in order to warm up and calibrate the BOD POD equipment. The Analyze Hardware, Check Scale, Autorun, and Volume functions were run, in order to effectively prepare and calibrate the equipment. Additionally, the scale associated with the BOD POD was calibrated once every two weeks. Performing those functions helped to ensure the most accurate results from the ADP testing.

Upon the participant's arrival to the testing facility, he was seated in the BOD POD room. The subject was then asked to read the informed consent carefully and thoroughly. The participant was encouraged to ask any questions regarding the informed consent. Once all their questions were answered, the participant was given the option to either choose to sign the informed consent and continue on with the scheduled testing, or refuse to sign the informed consent, no testing would be performed and they would be free to go. All subjects selected the former option and the testing commenced. The informed consent is available in **Appendix A**.

Once the informed consent was signed by the participant, the participant completed a screening and demographic questionnaire. If the participant met the study criteria of the screening and demographic questionnaire, they were asked to complete a physical activity questionnaire. Reasons for exclusion from this research study include answering false to any of the ten questions on the front page of the questionnaire. The physical activity questionnaire is available in **Appendix B**. The screening and demographic questionnaire is attached in **Appendix C**.

After the physical activity questionnaire was completed, the tester measured the participant's blood pressure via auscultation, using a stethoscope and a sphygmomanometer. The blood pressure was measured at this point because the subject would have been in a seated position for a minimum of five minutes. The blood pressure was measured in the participant's non-dominant arm, with the arm lying relaxed on the table. This blood pressure was recorded on the participant's data collection sheet. The participant then remained seated and the tester measured the subject's heart rate for one minute through their radial artery. This value was also documented on the subject's data collection sheet. To review a blank copy of the data collection sheet, see **Appendix D**.

In preparation for the ADP testing, the subject was then directed to change into the approved clothing for body composition testing. The approved clothing standard for men is compression shorts and a swim cap. The subject then removed shoes, socks, jewelry, and hair accessories and they changed into the compression shorts. The purpose of this specific clothing is to minimize the amount of error in the volumetric measurements taken by the BOD POD. If the participant did not bring acceptable clothing to be worn for testing, approved clothing was provided to him.

Once appropriately attired for testing, the participant's height was recorded to the nearest .1 centimeters. For the height measurement the subject was required to stand with his back touching the stadiometer with their heels together (as indicated on the stadiometer's baseplate). The subject's head was held within the Frankfort plane (parallel to the ground). The head plate was then lowered to the point in which it touches the subject's head. This value was also noted on the subject's data collection sheet.

The subject was then directed to step away from the stadiometer and remain standing comfortably, standing up straight and breathing normally. Using a Gulick tape, the tester first measured the WC of the subject at the narrowest point of the abdomen between the xiphoid process and the iliac crest. The tape was then tightened to remove slack and was maintained at a parallel position to the floor without being twisted. This resulting value was measured to the nearest .1 centimeter and recorded on the data collection sheet. The tape was then placed along the subject's transverse plane located at the umbilicus. The tape was again tightened and made parallel, measured to the nearest 0.1 centimeter, and recorded on the data collection sheet.

Next, the tester and subject moved into the BIA room. The printer and BIA machine were then turned on by the tester. The subject's information (age, gender, and height) was inputted into the BIA machine and placed in the kilogram and centimeter display mode while the subject stood on the silver panels of the BIA machine in his bare feet. The subject was instructed to grasp the two upper extremity portions of the BIA machine with his thumbs placed on the small silver recording panels. The BIA machine then performed the analysis and the results were printed off. This printed results sheet is kept with the data collection sheet, placed in the participant's file folder.

After the BIA testing, the subject was taken back into the BOD POD room for the SAD measurements. The subject went into a supine position on the examination table, and the SAD caliper was placed underneath the subject's lumbar spine, directly in line with the subject's umbilicus. The subject was first asked to breathe normally, and then three separate measurements are taken while the subject exhales and holds his breath for approximately three seconds. The top part of the caliper is lowered to touch the skin and a measurement is recorded to the nearest tenth of a centimeter. The three measurements are logged on the data collection sheet.

The final test performed is the BOD POD analysis. The subject's basic demographic information was inputted into the BOD POD computer by the tester, including participant identification number, height, and date of birth. The BOD POD was then calibrated one more time using the standardized volumetric cylinder. The subject was directed to put on the Lycra swim cap. This was important to ensure the accuracy of the volumetric measurement, due to the variability of trapped air associated with normal clothing and some hairstyles. The subject subsequently stepped onto the BOD POD scale and had his weight measured and recorded on the data collection sheet. Afterwards, the subject sat in the BOD POD chamber for two measurements of their volume. If the data between the first two tests is variable past the accepted threshold, a third test is performed to standardize and ensure the accuracy of the measurement. Each test lasted approximately 45 seconds. Upon successful completion, the subject changed back into his own clothing, was thanked, and escorted to the exit.

RESULTS

Data was collected from seven male subjects aged 57-68 years (Mean age of 61.57). The below table describes the data collected from the subjects.

Table 1. Description of Statistics of the Sample Population. Means and Standard Deviations.

Descriptive Statistics

	Mean	Std. Deviation	N
Age (Years)	61.57	4.504	7
Heart Rate (Bpm)	70.00	11.255	7
Systolic BP (mm Hg)	130.86	12.851	7
Diastolic BP (mm Hg)	82.00	8.246	7
BMI (kg/m^2)	26.643	3.6251	7
WC Narrow (cm)	92.886	8.7536	7
WC Umbilicus (cm)	94.371	8.4929	7
SAD (Avg.) (cm)	22.633	2.4269	7
BIA (%Fat)	22.829	3.1763	7
ADP (%Fat)	25.657	5.7029	7

Table 1 describes the mean values and standard deviations for each test performed. In addition to these mean values and standard deviations, frequency tables were created to evaluate how each test stratified each individual into various risk categories particular to each test. Below are charts that depict how subjects are stratified in accordance with each test. These charts include risk stratification based on blood pressure (hypertension risk), BMI, WC (narrow), WC (umbilicus), SAD, BIA, and ADP (BOD POD). Statistical analyses (including Pearson Correlations) were performed through SPSS software.

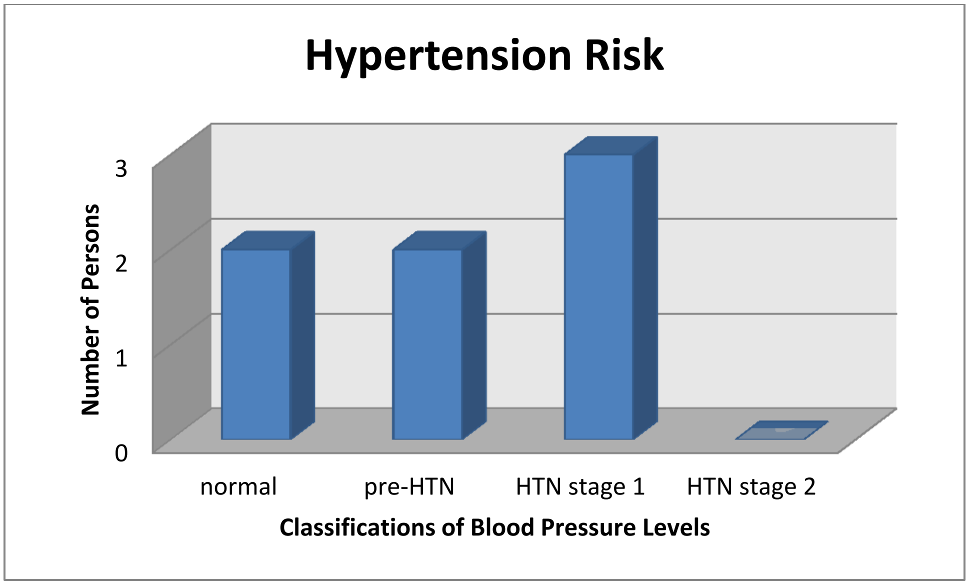

Figure 5. *Risk Stratification based on blood pressure levels indicating potential hypertension (HTN) risk.*

Hypertension risk is determined by both the systolic (while the heart is pumping blood) and diastolic (while the heart rests between beats) blood pressure values. Normal values for blood pressure are having a systolic blood pressure of less than 120 mm Hg and diastolic blood pressure of less than 80 mm Hg. Pre-hypertension is classified as having a systolic blood pressure between 120-139 mm Hg and or a diastolic blood pressure of 80-89 mm Hg. Stage I hypertension is classified as having a systolic blood pressure of 140-159 mm Hg and a diastolic blood pressure of 90-99 mm Hg. Stage II hypertension is classified as having a systolic blood pressure greater than 160 mm Hg or a diastolic blood pressure greater than100 mm Hg (American Heart Association, 2012). As noted in Figure 1, two subjects were classified as having normal blood pressure, two subjects classified as pre-hypertensive, and three subjects as hypertensive.

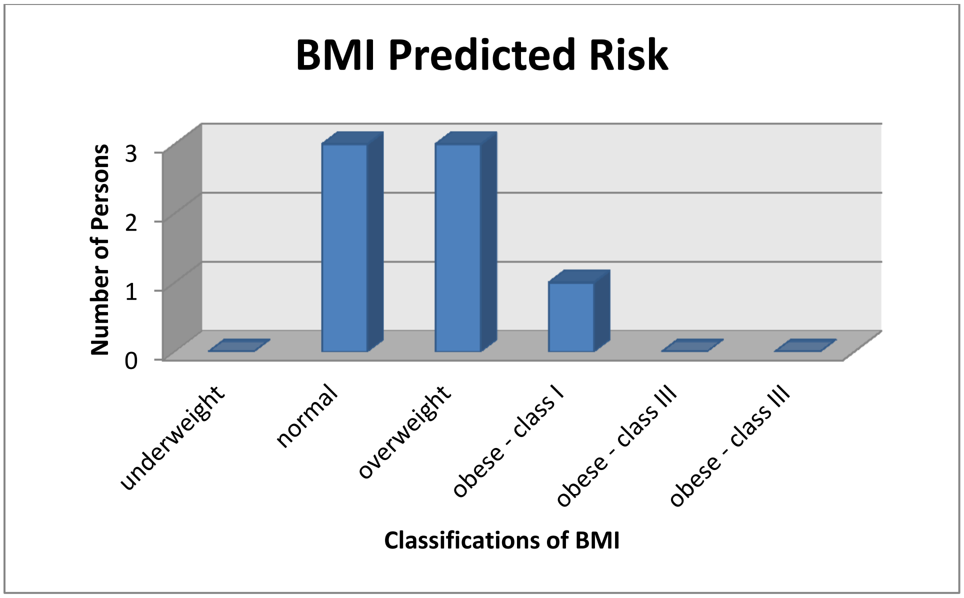

Figure 6. *Risk Stratification based on body mass index (BMI) scores*. Body mass index is a ratio of a person's height and weight.

Body mass index is calculated by dividing a subject's bodyweight in kilograms by their height in meters squared. Having a BMI of less than 18.5 kg/m^2 classifies a subject as underweight. A normal value for body mass index ranges from 18.5 kg/m^2 to 24.9 kg/m^2. A body mass index from 25.0 kg/m^2 to 29.9 kg/m^2 classifies the subject as overweight. A body mass index from 30.0 kg/m^2 to 34.9 kg/m^2 classifies the subject as being class I obese. A body mass index from 35.0 kg/m^2 to 39.9 kg/m^2 classifies the subject as being class II obese. A body mass index greater than 40.0 kg/m^2 classifies the subject as being class III obese (Centers for Disease Control and Prevention, 2011) BMI stratified three subjects as normal, three subjects as overweight, and one subject as class I obese.

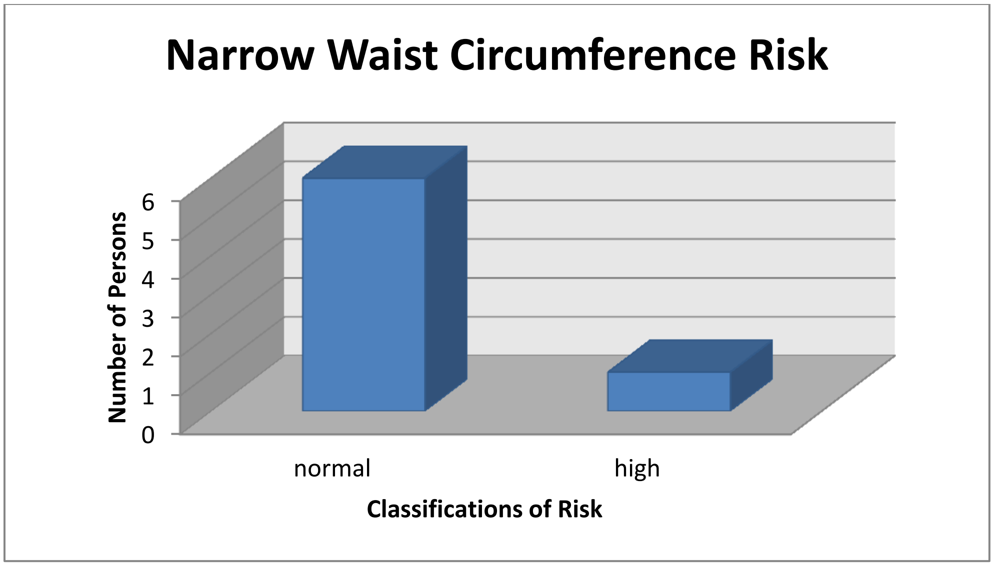

Figure 7. *Risk stratification based on narrow waist circumference measurements*. This measurement was taken at the narrowest point of the abdomen between the xiphoid process and the iliac crest of the hip.

The two classifications for WC are either normal risk or high risk for negative health consequences. A WC of less than 102 centimeters classifies the subject as normal risk. A WC of greater than 102 centimeters classifies the subject as high risk (National Heart, Lung, and Blood Institute, 2000). Note that the WC cutoff between normal and high risk is the same between WC measurements taken at the narrowest point and those taken at the umbilicus.

The below graph, Figure 8, indicates the same classification of risk as Figure 7, but is based on measurements taken at the umbilicus. Both WC measurement methodologies classified six subjects as normal risk and one subject as high risk.

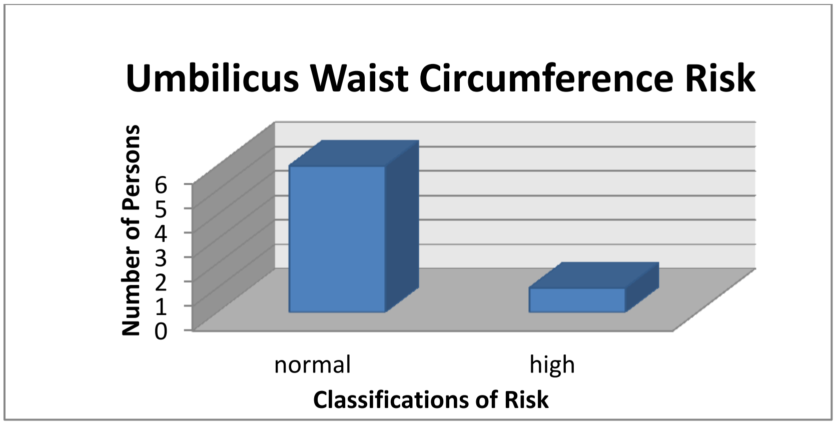

Figure 8. *Risk stratification based on the waist circumference measurement taken at the umbilicus.*

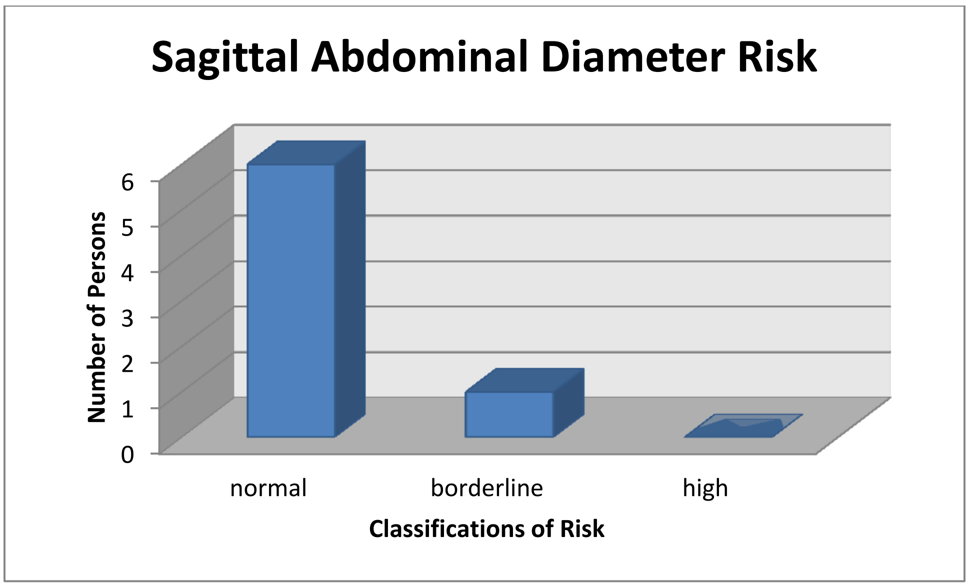

Figure 9. *Risk Stratification based on sagittal abdominal diameter measurements*. Three measurements were taken and the average value was used.

SAD stratifies subjects into normal risk, borderline-high risk, and high risk categories for negative health consequences. A SAD of less than 25.0 centimeters indicates normal risk. A SAD between 25.0 centimeters and 30.0 centimeters indicates borderline-high risk. A SAD greater than 30.0 centimeters indicates high risk. According to SAD measurements taken in the study, six subjects were at normal risk, and one subject was at high risk.

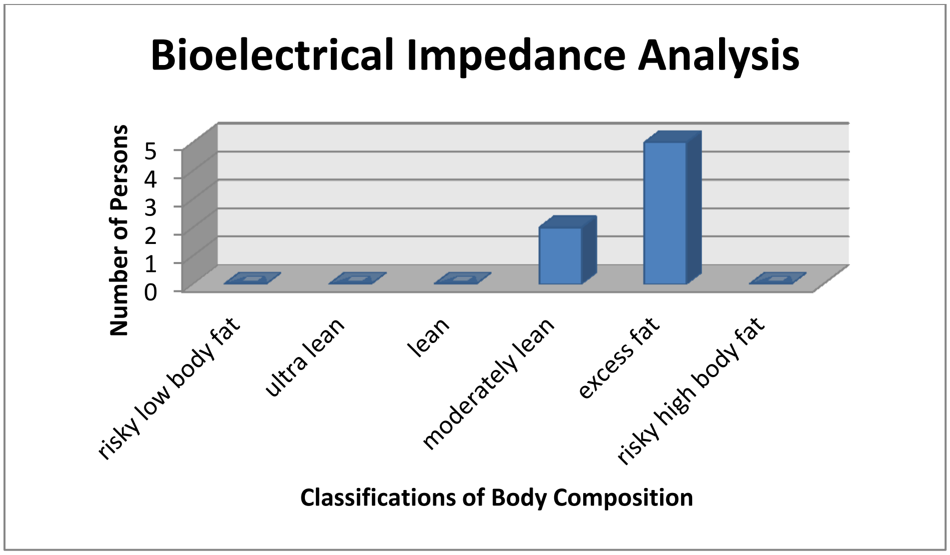

Figure 10. *Risk Stratification/Body Composition based on percentage body fat as determined by bioelectrical impedance analysis.*

There are six classifications of body composition based on the percentage body fat of the subject. Risky low body fat is a body fat percentage under 5.0. A body fat percentage between 5.0 and 8.9 is considered ultra-lean. A body fat percentage between 9.0 and 12.9 is considered lean. A body fat percentage between 13.0 and 20.9 is considered moderately lean. A body fat percentage between 21.0 and 29.9 is considered excess fat. A body fat percentage greater than 30.0 is considered risky high body fat (ACSM, 2014). According to these classifications, the BIA results classify two subjects as moderately lean and five subjects as having excess body fat.

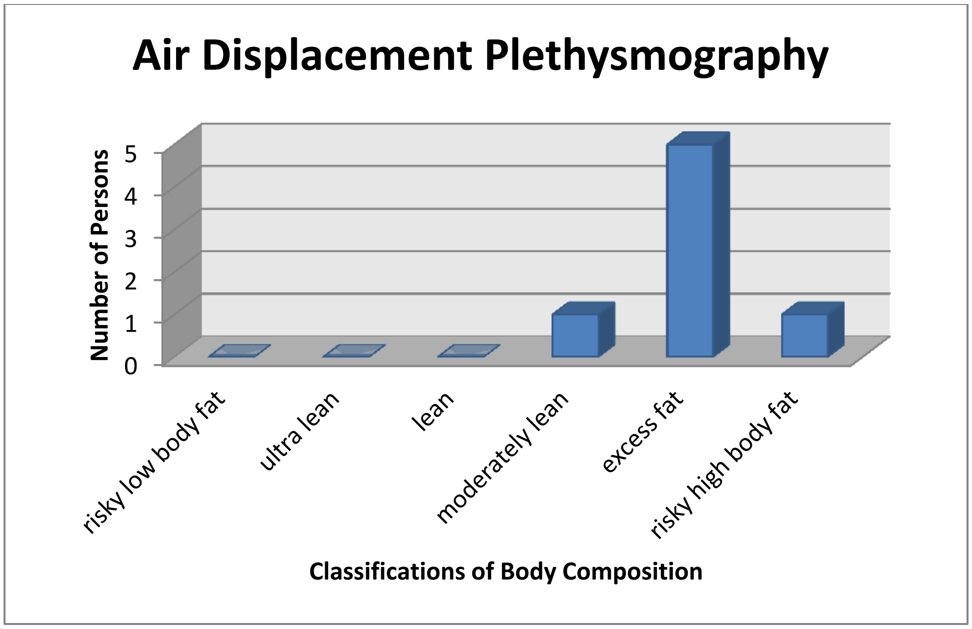

Figure 11. *Risk Stratification/Body Composition based on percentage body fat as determined by the BOD POD through air displacement plethysmography.*

Similarly to BIA scales, ADP determines a subject's percentage body fat using the same classification naming standards (ACSM, 2014). As shown in Figure 7, one subject was classified as moderately lean, five subjects were classified as having excess fat, and one subject was classified as having risky high body fat.

Table 2. *Correlation Matrix between body mass index, waist circumference at its narrowest and at the umbilicus, and sagittal abdominal diameter.*

	BMI	*WC Narrow*	*WC Umbilicus*	*SAD*
BMI	1			
WC Narrow	0.896	1		
WC Umbilicus	0.868	0.995	1	
SAD	0.921	0.976	0.970	1

* All correlations significant at the p<0.05 level.

Table 2 describes the most closely correlated and most significant methodologies. A correlation matrix between all methodologies and measurements performed is available in **Appendix E**.

DISCUSSION

From this study's findings there are three significant conclusions that can be drawn. The first conclusion can be drawn from the discrepancies in health risk stratification between BMI and ADP's determination of body fat percentage. BMI describes three subjects as normal weight, three subjects as overweight, and one subject as class I obese (see Figure 6). In comparison, ADP describes one subject as moderately lean, five people as excess fat, and one person as risky high body fat (see Figure 11). These two stratification methods show very different potential health outcomes of the test subjects. If only using BMI as a means of risk stratification, approximately half of the subjects would appear to be at normal risk. Using BMI would misclassify two of the seven subjects by underestimating their risk of developing negative health consequences. This stresses the importance and need for the implementation of a body composition tool that actually assesses percent body fat on an individual basis. BMI was not significantly correlated with ADP ($r=.483$, $p=.273$).

The traditional argument against BMI was that BMI will overestimate risk due to the subject's increased amount of muscle mass. This argument has been consistently validated in young adult male athletes. However, in the older male population the inverse relationship is true. BMI is underestimating the risk of the population to develop negative health consequences. This is an important finding, due to the continued growth of this population and the likelihood that this group's obesity prevalence is being underrepresented.

Also of note in the study results, BIA and ADP differed slightly in their risk stratification, even though both base their risk classification on the subject's body fat percentage. BIA underestimated the percent body fat in comparison to air displacement plethysmography in one of the seven subjects. This difference may be due to increased water weight often carried by men as they age or due to various electrolyte and ion levels within the subjects. Even with this slight differentiation, BIA was still much more closely related in risk stratification to ADP, when compared to BMI. BIA had a Pearson correlation of .746 and a p-value of .054 (approaching significance).

A second conclusion that can be drawn from results of this study is that a significant relationship between BMI, narrow WC, umbilicus WC and SAD was identified (see Table 2). When comparing BMI to the other methodologies of assessment listed in Table 2, the p-values were determined with narrow WC (p=.006), umbilicus WC (p=.012), and SAD (p=.004). All of these methodologies are significant on the p 0<.05 (95% confidence) level. Additionally, both WC measurements and SAD are significantly correlated on the p<0.01 (99% confidence) level. This is to be expected as they are all measuring the visceral fat of the abdomen.

The third result of note was that heart rate was significantly correlated with the percentage body fat as determined by BIA at the p=0.006 level (highly correlated with r=0.???). The p-value was equal to .006. This is interesting because the p-value between heart rate and the percent body fat as determined by the BOD POD was not significant (p-value=.130). In a larger sample size, it would be anticipated that heart rate would either be significant with both methodologies that calculate percentage body fat or not significant to either of the two methods.

<u>CONCLUSION AND RECOMMENDATIONS</u>

This study has found that, as anticipated, BMI is the least accurate of all of the methodologies tested in assessing health risk for a male adult over age 50. If feasible, a two compartment model that can distinguish between fat mass and fat-free mass (i.e., BIA or ADP) should be chosen over BMI, as well as being prioritized over the other anthropometric methodologies of WC and SAD for most accurate results. However, BIA and ADP equipment can be extremely expensive and thus not feasible in certain settings where funds are limited. In these situations, combining one of the significantly correlated anthropometric measurements along with BMI may help to validate risk stratification better than body mass index alone. Because the WC measurements and SAD are so closely related, only one of these methods needs to be performed in conjunction with BMI. By implementing different approaches, we may be able to better identify and target individuals at risk for negative health consequences, and therefore fight the obesity epidemic in our nation.

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Appendix A

Informed Consent for "Senior Health Study"

Introduction: You are being invited to participate in the "Senior Health Study." This project is collaboration between Dr. Amy Morgan, an associate professor of kinesiology, Dr. Mary-Jon Ludy, an assistant professor of clinical nutrition, Edward Kelley, a graduate student completing a master's degrees in kinesiology, and Cody Smith, an honors undergraduate student. We are interested studying the body composition status of older community members.

Purpose: The purpose of this study is to explore body composition measures in older populations. In general, the study will help to assess the need for better obesity classification standards in older Americans.

Benefits of being a participant include:

- A comprehensive body composition analysis testing session.
- Access to results and expert feedback after data is collected. This will include your testing results, which would cost approximately $200 at a health club.

Testing Date:

1. *Arrive at laboratory.*

   - You will arrive at Eppler South 124 at least 2-hours after exercise and eating/drinking anything other than water.

a. *Sign informed consent document.*
   a. You will read the informed consent document.
   b. You will ask any questions about participating in this study.
   c. After all your questions have been answered, you will have the option of:

Signing the informed consent (meaning that you agree to participate in this study), or

Deciding not to participate.

b. *Screening and demographic questionnaire.*

You will complete a questionnaire asking about: Your sex, age, ethnic/racial background, height, weight, phone number, and email.

(If applicable we will ask if you are claustrophobic)

Upon completion of informed consent and pre-testing questionnaires testing will begin.

Test Visit Procedures (45 minutes):

1. You will arrive at Eppler South 124 at least 2-hours after exercise and eating/drinking anything other than water.
2. You will sit while completing informed consent, demographic, and physical activity questionnaire.
3. Your blood pressure will be measured by placing a cuff around your upper arm.
4. You will dress in a swimsuit or tights shorts with sports bra (if applicable), swim cap, and nose plugs for your body composition measurements.
5. You will have your waist circumference measured by placing a measuring tape around your waist.
6. You will have your height measured while standing against the wall.

7. You will have your sagittal abdominal diameter measured while laying supine.

8. You will have your body composition measured using 2 methods.

Method 1 (BOD POD): You will sit in an airtight chamber for 2-3 brief measurements lasting approximately 45 seconds. *You should not participate in this measurement if you are claustrophobic.*

Method 2 (bioelectrical impedance): You will stand on an electronic scale and place your hands around handgrips. *You should not participate in this measurement if you have a pacemaker or other artificial electrical medical device/electrical system.*

9. You will dress in your own clothes.

After Data Collection

You will have access to your testing results. Your testing results will be available to you and research team members can answer any questions regarding your results.

Voluntary nature: Your participation is completely voluntary. You are free to withdraw at any time. You may decide to skip questions (or not do a particular task) or discontinue participation at any time without penalty. Deciding to participate or not will not affect your relationship with Bowling Green State University.

Confidentiality: Your participation in this study will remain confidential. Hard copies of all data will be stored in a locked filing room. The principal investigator, co-investigators, and graduate student assistants will be the only people with access to the data. The hard- copies will be retained for 3 years after the project ends, after which they will be destroyed by shredding. Electronic files will be stored on a portable flash drive in password-protected documents and will not be destroyed.

The study will not be anonymous because it will be necessary to identify participants before each test, as well as track and analyze results. Your name will be used when signing consent forms, at the screening visit, and when entering data into computer hardware for body composition testing. You will receive a “subject ID” number, which will be used on all paper documents after screening.

Risks: Risk may be encountered during body composition assessments and alcohol reporting.

b. BOD POD: There is a risk that participants will experience anxiety and/or uneasiness when placed in the confined windowed chamber. This procedure, involving 2-3 measurements of approximately 45 seconds, will be monitored by laboratory staff and can be discontinued at any point as necessary. The BOD POD also has a “panic button” that the subject may press at any point during the assessment to stop the test. To minimize this risk, potential participants reporting claustrophobia will be excluded at screening.

c. Bioelectrical impedance analysis: There is a risk that the small electrical signal transmitted through bioelectrical impedance analysis (to measure resistance of body tissues to the electrical flow, and thus estimate body fat and muscle mass) will interfere with implanted electrical devices. To avoid this risk, potential participants who report having a pacemaker or other artificial electrical medical device/electrical system will be excluded at screening.

Contact information: If you have any questions about this research or your participation in this research, please contact the study investigators.

Principal Investigator: Dr. Amy Morgan, Associate Professor School of HMSLS amorgan@bgsu.edu 419-372-0596

Co-Investigator: Dr. Mary-Jon Ludy, Assistant Professor School of FCS mludy@bgsu.edu 419-372-6461

Co-Investigator: Edward Kelley, Graduate Student School of HMSLS etkelle@bgsu.edu 419-372-0212

You may also contact the Chair, Human Subjects Review Board hsrb@bgsu.edu, if you have any questions about your rights as a participant in this research.

Thank you for your time.

I have been informed of the purposes, procedures, risks and benefits of this study. I have had the opportunity to have all my questions answered and I have been informed that my participation is completely voluntary. I agree to participate in this research.

_____________________________________ Participant Signature

Appendix B

Name: ___________________________________

Subject ID: _________________________________

Visit Date: _________________________________

PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities students do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do on campus, at work, to get from place to place, and in your spare time for recreation, exercise, or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   No vigorous physical activities ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

______ Don’t know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

No moderate physical activities ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

_____ Don’t know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

No walking ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

_____ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

_____ Don't know/Not sure

Thank you for completing the physical activity questionnaire!

Appendix C

Name: ________________________________

Subject ID: _____________________________

Visit Date: _____________________________

SCREENING AND DEMOGRAPHIC QUESTIONNAIRE

Please circle TRUE or FALSE for the following questions.

TRUE FALSE 1. I am not claustrophobic.

TRUE FALSE 2. I do not have a pacemaker or artificial electrical medical device(s)/electrical system(s).

TRUE FALSE 3. I am willing to attend 1 test visit lasting about 45 minutes each.

TRUE FALSE 4. I am willing to answer questions about my physical activity.

TRUE FALSE 5. I am willing to have my blood pressure measured.

TRUE FALSE 6. I am willing to have my weight measured.

TRUE FALSE 7. I am willing to have my height measured.

TRUE FALSE 8. I am willing to have my waist size measured.

TRUE FALSE 9. I am willing to have my abdomen measured.

TRUE FALSE 10. I am willing to wear a swimsuit or tight shorts with a sports bra (if applicable) to have my muscle and body fat measured.

Please fill-in or circle your answers to the following questions.

11. Sex: ______ male; ______ female

12. Age: ______ years

13. Birthday (month/day/year): ___________________________________

14. Ethnic/Racial Background

1. White/Caucasian (non-Hispanic)
2. Asian/Pacific Islander
3. Hispanic
4. Black/African American
5. American Indian/Alaskan
6. Other (name): ________________________
7. Prefer not to answer

15. Height: ______ inches

16. Weight: ______ pounds

17. Phone Number: __________________________

18. Email: ___________________________________

Thanks for completing the screening and demographic questionnaire!

Appendix D

Senior Health Study Data Collection Sheet

Participant ID: ____________________

Resting Blood Pressure: ___________________

Height (cm):_____________________

Waist Circumference (Narrow):_________________________

Waist Circumference (Umbilicus):______________________

Bioelectrical Impedance Analysis (% fat):___________________

Sagittal Abdominal Diameter (cm): Trial 1_____ Trial 2_____ Trial 3_____

BodPod: Fat Mass (kg)________ Lean Body Mass (kg)_________

Appendix E

Pearson correlation coefficients

Correlations

		Age	HR	Sys BP	Dia BP	BMI	WC Narrow	WC Umbilicus	SAD AVG.	BIA %FAT	BOD POD %FAT
Age	Pearson Correlation		-.270	.491	.386	-.479	-.264	-.183	-.166	-.512	-.052
	Sig. (2-tailed)		.559	.263	.393	.277	.567	.694	.722	.241	.912
HR	Pearson Correlation	-.270		-.088	.295	.570	.285	.238	.435	.901**	.629
	Sig. (2-tailed)	.559		.852	.521	.182	.536	.608	.330	.006	.130
Sys BP	Pearson Correlation	.491	-.088		.755*	-.189	.010	.062	.024	-.155	.461
	Sig. (2-tailed)	.263	.852		.050	.685	.983	.896	.959	.740	.298
Dia BP	Pearson Correlation	.386	.295	.755*		.087	.297	.325	.339	.277	.702
	Sig. (2-tailed)	.393	.521	.050		.852	.518	.478	.457	.547	.079
BMI	Pearson Correlation	-.479	.570	-.189	.087		.895**	.867*	.918**	.669	.483
	Sig. (2-tailed)	.277	.182	.685	.852		.006	.012	.004	.101	.273
WC Narrow	Pearson Correlation	-.264	.285	.010	.297	.895**		.995**	.974**	.419	.428
	Sig. (2-tailed)	.567	.536	.983	.518	.006		<0.001	<0.001	.350	.338
WC Umbilicus	Pearson Correlation	-.183	.238	.062	.325	.867*	.995**		.970**	.370	.441
	Sig. (2-tailed)	.694	.608	.896	.478	.012	<0.001		<0.001	.414	.323
SAD AVG.	Pearson Correlation	-.166	.435	.024	.339	.918**	.974**	.970**		.490	.484
	Sig. (2-tailed)	.722	.330	.959	.457	.004	.000	<0.001		.265	.271
BIA %FAT	Pearson Correlation	-.512	.901**	-.155	.277	.669	.419	.370	.490		.746
	Sig. (2-tailed)	.241	.006	.740	.547	.101	.350	.414	.265		.054
BOD POD %FAT	Pearson Correlation	-.052	.629	.461	.702	.483	.428	.441	.484	.746	
	Sig. (2-tailed)	.912	.130	.298	.079	.273	.338	.323	.271	.054	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).