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Determining the relationship between waist circumference, BIA, and ultrasound

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DETERMINING THE RELATIONSHIP BETWEEN WAIST CIRCUMFERENCE,
BIA, AND ULTRASOUND

A Thesis

Presented To

Eastern Washington University

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In Partial Fulfillment of the Requirements

for the Degree

Master of Science

By

Austin Nelson

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THESIS OF AUSTIN NELSON APPROVED BY

WENDY REPOVICH, GRADUATE COMMITTEE CHAIR

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CARRI KREIDER, GRADUATE STUDY COMMITTEE

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MASTER'S THESIS

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Chapter 1

Introduction

The United States is facing an obesity epidemic due to more than 30% of the population being above 30 on the BMI scale (CDC, 2009; Flegal, Ogden, & Curtin, 2010). No state met the *Healthy People 2010* objective of less than 15% obesity prevalence (CDC, 2009). Obesity prevalence has increased in Washington State steadily from 1999 – 2009 by nearly a percentage point each year and the fastest growth rate for obesity is between ages 18-34 (Washington State Department of Health, 2009).

Obesity and being overweight are associated with chronic diseases, including type 2 diabetes, cardiovascular disease, hypertension, and certain forms of cancer that result in premature death (Washington State Department of Health, 2009; Williams, et al., 1992; World Health Organization, 2003). Due to the relationship among cardiorespiratory fitness, body composition, and physical activity, a person who develops one or more of the previous diseases often will die sooner if they are obese compared to those who were not obese (Lohman et al., 2008).

While obesity measured by BMI by is suggestive of risk, fat distribution appears to be a more important variable than total body fat in terms of risk for cardiovascular disease (Glaner, Lima, & Borysiuk, 2010). Because greater fat mass around the trunk region is generally associated with this higher a measurement of the trunk region should prove useful in screening people (Glaner, Lima, & Borysiuk, 2010). Both men and women with higher waist to hip ratios have shown stronger associations to encounter cardiovascular disease even when controlling for BMI, cancer and/or smoking (Hafe,

Pina, Tavares, & Barros, 2004, Lapidus et al., 1984; Larson et al., 1984; Oppert et al., 2002).

Values of waist WC are consistently related to developing coronary heart disease (CHD), while both the lowest and highest categories of WC remain significant after adjustment for BMI for predicting CHD and diabetes (Klein et al., 2007). The WC measurement itself is important and can be combined with BMI as *The American College of Sports Medicine in their Guidelines for Exercise Testing and Prescription* (2010) recommend combining a WC with BMI for the purpose of risk stratification. ACSM acknowledges that BMI and WC can be used separately but still recommends using BMI and WC when it is an option because abdominal obesity is a primary issue for being an indicator of being at health risk (ACSM, 2010).

Abdominal adiposity has been designated as an independent cardiometabolic disease risk factor (Janiszewski, Janssen, & Ross, 2007, Klein et al., 2007, & Ross et al., 2008) among other risk factors such as age, hypertriglyceridemia, hypertension and high fasting glucose, a group of risk factors that when combined increase risk exponentially, called metabolic syndrome (Després, Lemieux, Bergeron, Pibarot, Mathieu, Laros et al., 2008, Ford & Giles, 2003). Abdominal obesity is a risk factor because there is subcutaneous fat (SAT) that is under the skin and deeper fat called visceral fat (VAT), which surrounds the organs. The amount of visceral fat that can accompany abdominal obesity is what puts a person at risk for metabolic syndrome. Every one-centimeter incremental increase in waist circumference (WC) has shown increases of 6.8 cm² of visceral adipose tissue (VAT) in men and 3 cm² of VAT in women, who have metabolic syndrome (Onat et al., 2004).

As an external measure, WC cannot distinguish between SAT and VAT, but currently there are several measurement techniques that can, including Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Ultrasound (US). VAT is an important factor in screening for cardiometabolic disease risks and WC is an affordable and time efficient alternative to CT, MRI, and US, to indirectly measure VAT in people (Bosy-Westphal et al., 2010, Carr et al., 2004). Ultrasound has been shown to be valid in older adults when compared to an MRI (Rolfe, et. al., 2010; Stolk, Wink, Zelissen, Van Gils, & Grobbee, 2000). Tanita has the BC-418 Segment body composition analyzer (Tanita, Tokyo, Japan) that has a trunk measure of percent body fat estimation, which has been validated against dual energy x-ray absorptiometry (DEXA) (Pietrobelli, Rubiano, St-Onge, & Heymsfield, 2004).

The American Heart Association (AHA), National Cholesterol Education Program (NCEP), National Heart Blood and Lung Institute (NHLBI), National Institutes of Health of Health (NIH) and the International Diabetes Foundation (IDF) all have WC in their screening guidelines, and these organizations believe that WC should be used to help screen people for risk of having or getting cardiometabolic disease (Carr et al., 2004; Serviente & Sforzo, 2013). Unfortunately, these organizations and other organizations there is no clear or consistent way to perform a WC measurement due to different protocols using different sites for what is considered a person's waist. The three main sites used for WC are below the lowest rib, level at the umbilicus, and superior to the iliac crest and the other two sites that can be used are minimal waist and midway between the lowest palpable rib and the iliac crest (ACSM, 2010; Serviente & Sforzo, 2013). The issue with different WC sites and one set of cut off points is that this leads to

misclassification of people by placing more people in an at risk category due to the WC at the level of the umbilicus when compared to minimal waist (Willis et al., 2007).

Obesity has become a problem that needs to be addressed in the United States. Obesity itself is not as important as the abdominal obesity a person carries, more particularly VAT. There are 5 different WC sites used with only one set of cut-off points for all 5 WC sites (Serviente & Sforzo, 2013). No studies have tried to find a correlation of VAT between WC and US or WC and BIA. If it is possible to determine which of the various WC sites have the strongest correlation with a measure of VAT, than that site could be the recommended measurement and could start a standardization protocol for WC. Therefore, the purpose of this study is to assess if there is a correlation between any of the three main WC sites and either BIA and/or ultrasound.

Hypothesis

H₀: There will be no significant correlations between three waist circumference sites: below the lowest rib; at the level of the umbilicus; and superior to the iliac crest; with BMI; BIA trunk; or US VAT depth.

H_a: There will be a significant positive correlation between three waist circumference sites: below the lowest rib; at the level of the umbilicus; and superior to the iliac crest; with BMI; BIA trunk; and US VAT depth.

Operational Definitions

BIA: Trunk % fat was measured by the TANITA BC-418 Segmental Body Composition Analyzer.

Body Mass Index: Body mass index (BMI), the ratio of height to weight was determined using weight in kilograms divided by height in meters squared.

SCAT & VAT: BodyMetrix portable ultrasound was used to assess SCAT, and VAT depth.

Waist circumference: The three waist measurements, just below the lowest palpable rib, at the level of the umbilicus, and superior to the iliac crest were measured using a Gulick tape.

Assumptions

For body composition measurement with BIA, it is important that the subject is in a rested and hydrated state. It is assumed that the subjects will refrain from exercise 24hrs prior to testing and normal fluid intake is maintained for accurate readings.

Delimitations

The population will be delimited to 72 subjects consisting of men and women ages 18 - 55 that were divided into groups of overweight, BMI score $\geq 26 \text{ kg/m}^2$ to 29.9 kg/m^2 and a obese, BMI score $\geq 30 \text{ kg/m}^2$.

Summary

This chapter presented the problem of obesity and the implications for being over fat in the United States and how Washington State has been affected by the obesity problem and more important than obesity is VAT depth. The primary purpose of this study was to determine the relationship between waist circumference measurements and ultrasound and BIA. Currently, there is no standard for waist circumference measurements. This research was a step towards scientifically choosing an appropriate waist circumference site.

Chapter 2

Review of Literature

Introduction

The purpose of this research was to determine the relationship between waist circumference measurements and ultrasound and BIA to help further research toward a standard protocol for waist circumference measurements. A review of the current literature will cover the implications and risks for being over fat and measurement issues around obesity, and how WC may help with screening people for certain disease risk factors.

Implications for being over fat

The need of effective interventions to reduce obesity and related health risks have increased in recent decades due to obesity levels in adults and children have reached epidemic proportions. The modern environment allows people easier access to make unhealthy choices that result in an increased consumption of food, and reduced physical activity. Population approaches for obesity, strive to promote energy balance and physical activity (Kumanyika, Obarzanek, Stettler et al., 2008). This all started in the late 1980's.

Between 1960 and 1974 the age adjusted prevalence of obesity only increased 1.1% using the National Health and Nutrition Examination Survey I (NHANES) data (CDC, 2008). It was not until NHANES III took place from 1988-1994 that the first big increase in obesity prevalence in the United States was found, which was an average increase of 8% among men and women (Flegal, Ogden, & Curtin, 2010). This was probably the beginning of the obesity epidemic in the United States. From 1980-2000

obesity prevalence has more than doubled in the US. This is important because by 1980 obesity prevalence was estimated at 15% and by 1994 an 8 % increase was observed bringing obesity prevalence to 23.2 %. The next increase (7.5%) led to a 30.9% obesity prevalence suggesting that the rate of obesity may be slowing down due to a lower percentage increase than before (CDC, 2008; Flegal et al., 2010). Even though the prevalence of obesity may be slowing down, the United States is still currently facing an obesity epidemic due to more than 30% of the population being above 30 on the BMI scale nationally, not one state met the *Healthy People 2010* objective, which was to have less than 15% obesity prevalence (CDC, 2009). Less than 15% obesity prevalence may have been too big of a goal because by 2008 the age-adjusted prevalence of obesity (BMI ≥ 30.0) was 33.8% overall in the United States (Flegal et al., 2010). In Washington State alone, obesity prevalence has increased steadily from 1999 – 2009 by nearly a percentage point each year with the fastest growth rate for obesity in the age group 18-34 meaning that the younger generation in Washington state could face bigger health problems and higher health care cost if they do not take control over their obesity rate (Washington State Department of Health (DOH), 2009).

The rising prevalence of obesity is important because there are implications that go along with obesity. Obesity, and also being overweight are associated with chronic diseases, including type 2 diabetes, cardiovascular disease, hypertension and high total cholesterol, and certain forms of cancer that result in premature death (DOH, 2009; Williams, et al., 1992; World Health Organization, 2003). There is a relationship that exists between a person's cardiorespiratory fitness, body composition, and physical activity, and the relationship is, that a person who develops one or more of the previous

diseases, often will die sooner if they are obese compared to those who are not obese (Lohman et al., 2008). The prevalence of obesity may actually be higher than reported because a lot of the population studies use self reported data (CDC, 2009).

In 2009, self reported body mass index scores (BMI) and body weight of Americans lead to an obesity prevalence of 26.7% across America (CDC, 2009). That is 7.2 percentage points lower than the 2007-2008 NHANES report of 33.9% (CDC, 2009). The discrepancy is probably from self-reported data versus actually measuring people for accurate data.

Validity of self-reported height, weight, and BMI from the NHANES survey from 2001-2006 was tested (Merrill & Richardson, 2009) and the results help explain why the CDC report statistics that may have obesity prevalence predicted lower than it may actually be. The researchers who tested the validity of self reported data found that both men and woman over report their height increasingly at older ages. Men over report their height by 1.22cm (0.48 in) and women over report height by .68cm (0.27 in). Men have a tendency to overestimate their weight by .30kg (.66lbs) while women under reported their weight by about -1.39 kg (-3.06 lbs) (Merrill & Richardson, 2009). Although these examples appear to be minimal in values, over reporting height and weight will have a direct impact on a BMI score. An example being that if a man overestimates his height (about .5 inch) and weight (about .5lb) than a self reported 6' male weighing 220.5lbs would have a BMI score of 29.9 placing him in the overweight category when in reality he is 5' 11.5" weighing 220lbs, his actual BMI score would be 30.3 placing him in the obese category. Male or female, if they are close to a cut off point there is an opportunity for misclassification by self-reporting information.

Mortality risk appears to vary by BMI categories. Using NHANES surveys, a significant increase in all-cause mortality in the underweight and obese categories were observed, while significant decrease in all-cause mortality was observed in the overweight category when compared to the normal weight groups (Flegal, Graubard, & Williamson, 2005). In a follow up study the authors estimated excess all-cause mortality associations with underweight, overweight, and obesity in the United States using data from the NHANES surveys (Flegal, Graubard, Williamson, & Gail, 2007). The follow up involved information from the NHANES I, 1971-1975; II, 1976-1980; and III, 1988-1994, with mortality follow up through the year 2000, combined with underlying cause of death information for 2.3 million adults 25 years and older from the 2004 vital statistics data for the United States (Flegal et al., 2007). Mortality was split into cardiovascular disease (CVD) mortality, cancer mortality and noncancer, non-CVD mortality.

In 2004 cardiovascular disease accounted for 37% of adult deaths in the United States (Flegal et al., 2007). For CVD mortality, obesity, but not overweight, was significantly positively associated with excess mortality. A person's level of fitness influences their body weight. Usually more active people have lower body weight or body fat which is why higher levels of physical fitness appear to delay all-cause mortality due primarily to lower rates of cardiovascular disease (Blair et al., 1989). During a secondary analysis (Flegal et al., 2007) where CVD was split to coronary heart disease (CHD) and deaths from other cardiovascular events including strokes, obesity was significantly associated with increased mortality from both CHD (45,544 excess deaths; 95% CI, 24,785-66,303) and other forms of CVD (34,097 excess deaths; 95%CI, 213,848-54,346). Based on mortality rates of CVD cases, a person classified as over

weight (BMI 25- < 30) maybe should not be instructed by healthcare professionals to lose weight or gain any further weight.

Cancer accounted for approximately 24% of total deaths in adults in the United States (Flegal et al., 2007). For cancer mortality there was little or no significant findings or associations of excess mortality with any BMI category (Flegal et al., 2007) Noncancer, non-CVD deaths accounted for approximately 39% of total deaths among adults in the United States in 2004 (Flegal et al., 2007).

When the sample was split to underweight and obese, the underweight group of the noncancer, non-CVD mortality category, was associated with significantly positive number of excess deaths while the overweight group had a significantly negative number of excess deaths. Jiang He and colleagues found similar results when they reported the association between being underweight had an increased risk of death which remained significant after exclusion of study participants who were current or former smokers; those who had prevalent CVD, stroke, cancer, or end-stage renal disease; those who had chronic obstructive pulmonary disease at the baseline examination; or those who died during the first three years of follow-up (He et al., 2005). Obese groups were not associated with any significant findings, positive or negative, in excess noncancer, non-CVD mortality. Having no cancer conditions and no CVD events and being underweight (BMI < 18.5) a person may want to try to gain weight for decreased mortality especially in women because underweight women had a higher relative risk of mortality than underweight men but moderately/extremely obese women had a lower relative risk of mortality than men in the same category (Flegal et al., 2007; He et al., 2005; Strawbridge, Wallhagen, & Shema, 2000).

People who rate on a cutoff point may think they are not endangered or at risk of the diseases associated with being obese, which is why we need an accurate way to measure adipose tissue (Flegal et. al. 2005). It is important not to put emphasis on obesity because if you force the public or scare the public to lose weight they could place themselves in harms way as they get older by trying to maintain low BMI scores (Strawbridge et al., 2000).

Measurements

There are various measurement devices used in body composition research. Some instruments are less expensive and also time efficient such as calculating a BMI score and measuring WC which is relatively easy to do and can be completed in a variety of settings. Other instruments, such as a bioelectrical impedance analysis (Tanita BC-418 Segmental Body Composition Analyzer) and a portable ultrasound (IntelaMetrix, Inc., Livermore, CA) are usually found in research settings and they cost more, not time efficient, and require someone to administer the assessment which makes these options less ideal for large populations.

BMI.

Body mass index (BMI) is an index that places a person in a classification of weight status that varies from underweight to obese. The BMI calculation is weight in kilograms divided by the square of height in meters (kg/m^2). The calculation does not use age or the gender of a person in the equation (CDC, 2008; WHO, 2008).

The various classifications of BMI are as follows; Underweight <18.50 , Normal $18.50-24.99$, Overweight ≥ 25.00 , Obese ≥ 30.00 . The obese classification has three different classes which are Obese class I $30.00-34.99$, Obese class II $35.00-39.99$ and Obese class

$\text{III} \geq 40.00$. The WHO has recognized and is still continuing research on the possibility of establishing different cutoff points for different ethnic groups. The WHO is responding to more evidence that suggest the association between BMI, body fat distribution, and percentage of body fat may differ across different populations. The focus has been on the breakpoint for the Overweight classification ≥ 25.00 . Health risk may increase below this cutoff due to populations who have lower body weights but higher body fat percentages, for example Asian and Pacific Islander populations (WHO, 2004).

The WHO expert consultation team acknowledged the Pacific Islander population as well for having a low proportion of fat mass to lean mass but still have some of the highest rates of obesity in the world (WHO, 2004). The recommendation is that all populations with a predisposition to central obesity and have an increased risk for developing metabolic syndrome should include a waist circumference measurement as well (WHO, 2004). Further research is needed to address BMI with waist circumference in various populations to generate new standards. BMI has been combined with waist circumference in the past.

BMI with Waist Measurement.

Using data from the 1999-2004 NHANES, researchers sought to see if WC could in fact predict diabetes and cardiometabolic risk factors beyond that explained by BMI alone (Janiszewski et al., 2007). After inclusion of BMI and cardiometabolic risk factors and controlling for age, sex, race and smoking, WC still remained significant in medium to high WC measurements for predicting diabetes in this population (Janiszewski et al., 2007). The relation between WC and clinical outcome is consistently strong for diabetes

risk, and WC is a stronger predictor of diabetes than BMI alone (Klein et al., 2007).

Values of WC are also consistently related to developing CHD, while both the lowest and highest categories of WC remain significant after adjustment for BMI for predicting CHD and diabetes (Klein et al., 2007).

BMI and waist circumference (WC) independently help with predicting body fat on a person. Waist circumference has been correlated to total fat mass $R^2 = 0.87$ women and 0.68 for men but BMI has shown a stronger correlation with total fat mass $R^2 = 0.92$ women and 0.78 for men (Janssen, Heymsfield, Allison, Kotler, & Ross, 2002). The American College of Sports Medicine in their *Guidelines for Exercise Testing and Prescription* (9ed) recommend combining a WC with BMI for the purpose of risk stratification. ACSM acknowledges that BMI and WC can be used separately but still recommends using BMI and WC when it is an option because abdominal obesity is a primary issue for being an indicator of being at health risk (ACSM, 2010). No organization has yet adopted a standard protocol for determining which WC should go with BMI.

Waist Circumference.

Abdominal adiposity is a cardiometabolic disease risk factor (Janiszewski et al., 2007; Klein et al., 2007; Ross et al., 2008) among other risk factors such as age, hypertriglyceridemia, hypertension and high fasting glucose (Després et al. 2008, Ford & Giles, 2003). Every 1cm increment in WC has shown increases of 6.8cm² of VAT in men and 3cm² of VAT in women, who have metabolic syndrome (Onat et al., 2004). WC compared to computerized tomography (CT) in women has shown that WC to intra-abdominal fat volume had a correlation of 0.889 (Han, McNeil, & Lean, 1997). WC itself

cannot distinguish between SAT and VAT but VAT is an important factor in screening for cardiometabolic disease risks and WC is an affordable and time efficient alternative to CT or MRI to indirectly measure visceral adipose tissue (VAT) in people (Bosy-Westphal et al., 2010, Carr et al., 2004).

Besides cardiometabolic disease, cardiovascular disease and type 2 diabetes have also been linked to high WC measurements. The population used was 5,882 people from the NHANES III. Individuals with high WC were 73% more likely to have cardiovascular disease than individuals with lower WC but after controlling for cardiometabolic risk factors the interaction was not significant. After controlling for cardiometabolic risk factors and including BMI, WC predicted type 2 diabetes in medium to high WC measurements meaning that WC in this study predicted type 2 diabetes but not cardiovascular disease (Janiszewski et al., 2007). Others have found that in both men and women with higher waist to hip circumferences have shown stronger associations to encounter CVD even when BMI, cancer, and smoking are controlled for (Lapidus, Bengtsson, Larson, Pennert, Rybo, & Sjostrom, 1984; Larson, Svärdsudd, Welin, Wilhelmsen, Björntorp, & Tibblin, 1984; Oppert, Charles, Thibult, Guy-Grand, Eschwége, & Ducimetière, 2002).

There is no consensus on the most appropriate WC measurement technique and the American Heart Association (AHA), National Heart Blood and Lung Institute (NHLBI), National Institutes of Health (NIH) and the International Diabetes Foundation (IDF) all have WC in their screening guidelines. This causes confusion for exercise professionals and allied health care workers as to which site and protocol to use or even if it matters (Serviente & Sforzo, 2013) These organizations believe that WC should be

used to help screen people for risk of having or getting cardiometabolic disease (Carr et al., 2004, Serviente & Sforzo, 2013). Intra-abdominal fat has been independently associated with all of the metabolic syndrome criteria (Carr et al., 2004). While they all agree that WC should be done between these organizations there is no clear or definite way to perform a WC measurement due to different protocols using different sites for what is considered a person's waist. The American College of Sports Medicine (ACSM) has recommended one set of cut off points for WC measurements and they are >102 cm for men and >88 cm for women which places them in a high risk category (ACSM, 2007). The downfall to these cut off points is that various organizations use different sites to measure WC to obtain these measurements, causing either more people to be placed at high risk or less people to be placed at high risk, depending on the site used.

WC current recommendations.

The WHO recommends that the WC measurement be made at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest (WHO, 2008). ACSM recommends using the narrowest part of the torso (ACSM, 2010). The AHA, NHLBI and NIH recommend the point superior to the iliac crest (Cornier, Després, & Davis, 2011, NHLBI, 1998, NIH, 2000). The IDF offers different cut off points for various parts of the world but they offer no protocol to be used (IDF, 2006).

Difference between sites.

In terms of body fat and not disease risk, all five WC sites (measured at immediately below the lowest rib, narrowest waist, midpoint between the lowest rib and the iliac crest and immediately above the iliac crest) were compared to DEXA and found that the WC site superior to the iliac crest had the highest correlation to total body fat in

men and women (Wang et al., 2003). No matter which site is chosen, each WC measurement appears to be reliable (Mason & Katzmarzyk, 2009).

When following specific instruction, there is good reliability for all measures. Intraobserver reliability via intra class correlations were $r = .989$, $r = 0.991$, $r = 0.992$, and $r = 0.993$ for the following WC sites in order; the narrowest part of the waist, midpoint between the iliac crest, and below the lowest rib, at the level of the umbilicus, and immediately above the iliac crest in 542 predominantly white men and women aged 20-67 years old (Mason & Katzmarzyk, 2009). Corresponding ICCs for interobserver reliability were $r = 0.989$, $r = 0.987$, $r = 0.987$, $r = 0.987$ suggesting the magnitude of the WC measurement is influenced by the protocol chosen, more so in women than in men (Mason & Katzmarzyk, 2009). In men and women the highest mean values have been reported at the umbilicus site and the smallest mean at the narrowest (Mason & Katzmarzyk, 2009). Similar results were found in 111 subjects using the same WC sites, researchers determined that men measured at the narrowest part of the waist lead to a WC mean that was significantly smaller than the other three sites, but females, the mean for each site was significantly different from all other means from the other sites (Wang et al., 2003). The various WC sites are reliable no matter which site is used, but the sites themselves differ in magnitude and small differences are amplified when an exact cut off point is used, rather than a continuum, to define abdominal obesity (Mason & Katzmarzyk, 2009; Wang et al., 2003). It is important to take into consideration as to which site to choose, otherwise you may have a conservative estimate or liberal estimate (especially in women) who may be at risk for obesity and this is why adopting a standard

measurement protocol will facilitate the interpretation and clinical utility of WC for obesity-related risk stratification (Mason & Katzmarzyk, 2009)

Currently, major health organizations such as the NHLBI use the cut off points of men WC ≥ 102 cm and women WC ≥ 88 cm (NHLBI, 1998). The controversy of these cut off points is that they were developed using the WC site midway between the lowest rib and the iliac crest (Lean, Han, & Morrison, 1995). NHLBI recommends using the WC site superior to the iliac crest but uses cut offs that were developed from a different site (NHLBI, 1998). The cut off points of men WC ≥ 102 cm and women WC ≥ 88 cm were derived from a big sample (904 men & 1014 women) in Glasgow, Scotland and are based on the association with BMI and WC (Lean et al., 1995). The research was for weight management and the key messages were that most men with a waist circumference ≥ 102 cm and women with a waist circumference ≥ 88 cm were appreciably overweight or had a high waist to hip ratio and should be urged to lose weight and men with WC 94-102 cm and women with a WC 80-88 cm should be careful to avoid more weight gain (Lean et al., 1995). The practice of using cut off points based only on BMI and on one WC site and interchangeably using those cut off points for other WC sites may lead to a lot of misclassifications of people who may need to know if they are at risk of disease (Wang et al., 2003).

With one set of cut off points for all five WC sites, using the various WC sites could lead to misclassification of obesity. In men and women the highest mean values have been reported at the umbilicus site and the smallest mean at the narrowest waist so using these sites your (Mason & Katzmarzyk, 2009).

An example of misclassification of health risk is a study that compared the minimal waist and the umbilical sites (Willis et al., 2007). Instead of using BMI (Lean et al., 1995) researchers used intravenous glucose tolerance test, fasting plasma lipid analysis and computed tomography scans were conducted. In both men and women the minimal waist site had stronger correlations to cardiovascular disease risk factors and metabolic syndrome than the umbilicus site. Using the Adult Treatment Panel (ATP) III criteria and using the cut off points of men $WC \geq 102\text{cm}$ and women $WC \geq 88\text{cm}$, the site used made a difference. Using the umbilical site with these cut off points, it placed 54% more men and 68% more women at or above the cut off points (Willis et al., 2007).

Comparing umbilicus, midpoint between the lowest rib and the iliac crest, superior to the iliac crest and minimal waist sites, to find out if a measurement site will affect cardiometabolic risk classification using the cut off points of men $WC \geq 102\text{cm}$ and women $WC \geq 88\text{cm}$ (Lean et al., 1995), researchers tested each of these sites for sensitivity and specificity (Mason & Katzmarzyk, 2010). In both sexes, WC at the umbilicus showed greater sensitivity but less specificity meaning better at predicting the presence of disease and not as good as showing absence of disease. (Mason & Katzmarzyk, 2010, Serviente & Sforzo, 2013). Measurements at the minimal waist showed less sensitivity but greater specificity at detecting ≥ 2 risk factors for cardiometabolic disease. Using the widely accepted cut off points of men $WC \geq 102\text{cm}$ and women $WC \geq 88\text{cm}$ (Lean et al., 1995), the magnitude of WC is affected by the measurement site chosen. Using minimal waist for the men, only placed 23% of them into high health risk ($>102\text{ cm}$) while using the umbilicus site, 34% of the men met $>102\text{ cm}$. In women 31% were $> 88\text{cm}$ and using the minimal waist site and the umbilicus site

placed 55% of the women above 88 cm (Mason & Katzmarzyk, 2009). This variation demonstrates the need to have a single WC measurement site and cut off points to go with that site to classify people in a health risk category.

As far as choosing the site to pick for standardization protocol for WC there is an even bigger debate than interchanging cut off points for different sites. Currently there is no agreement on the absolute best site for WC (Serviente & Sforzo, 2013). Three WC sites (below the lowest palpable rib, superior to the iliac crest and midway between the lowest rib and the iliac crest) have been tested to see if a site is better than another based on volume of VAT and SAT from a MRI, along with cardiometabolic risk factors such as blood pressure, plasma lipids, homeostasis model (HOMA index) and glucose (Bosy-Westphal et al., 2010). After a dietary intervention, below the lowest palpable rib was the only site that predicted weight loss associated with a decrease in VAT, but in women only. The site superior to the iliac crest had very low association with VAT and cardiometabolic risk factors in women. In men and children all three sites had similar relations to VAT, SAT and cardiometabolic risk factors (Bosy-Westphal et al., 2010). The site below the lowest palpable rib showed the best correlations to pick a site for both sexes in terms of total VAT and cardiometabolic risk factors ($r = 0.74$ men, $r = 0.70$ in women) and men midway between the lowest palpable rib and the iliac crest had similar results as the lowest palpable rib site (Bosy-Westphal et al., 2010).

In men CT has shown that at L1-L2 and L2-L3 have significantly higher correlations ($R^2 = 0.96$, $P < 0.05$) with total volume of fat and lower SEEs than all other images taken by CT scans from T11-S1 (Kuk, Church, Blair, & Ross, 2006). Women that were measured at the midway between the lowest rib and the iliac crest were

compared to MRI and CT scans and 2/3 of the distance instead of midway showed $r = 0.99$ for predicting intra-abdominal fat (Han et al., 1997). These previously described studies give evidence to the need to identify the best site of WC to predict disease risk.

Although WC has been shown to be highly reliable across all sites and WC has a strong correlation to body fat, cardiovascular disease and metabolic syndrome risk factors there is still no standard protocol and some WC measurements may miss classify more people than other WC sites (Klipstein-Grobusch, Georg, & Boeing, 1997; Mason & Katzmarzyk, 2010, & Wang et al., 2003; Willis et al., 2007). VAT is an important factor in screening for cardiometabolic disease risks and WC is an affordable and time efficient alternative to CT or MRI to indirectly measure VAT in people (Bosy-Westphal et al., 2010, Carr et al., 2004). There are other instruments that can measure the trunk region as well.

BIA.

Bioelectrical Impedance Analysis (BIA) is a noninvasive method that is used to evaluate a person's body composition. BIA measures the bioelectrical impedance of the body by applying a low-level electrical current through the body. The Tanita Body Composition Analyzer uses a high frequency constant current (50kHz, 500uA). Fat mass allows minimal electrical current to pass through where as water allows electrical current to flow through with little resistance, especially in the human body where the water content tends to hold electrolytes which are also great conductors of electricity (Heyward & Wagner, 2004). The electrical resistance measured or impedance, measured in BIA is the difficulty with which electricity passes through the body. Body fat percentage, muscle

mass and total body water can be inferred by measuring the electrical resistance of the body.

BIA has seen a lot of changes in the last 25 years due to technological advances. The original BIA method, which is still used, involves placing electrodes at the wrist and ankles. This method alone has opened up numerous research opportunities involving standardizing placement of electrodes, various frequency's used, and the errors associated with subjects in various hydration states (Baumgartner, Chumlea, & Roche, 1989, Houtkooper, Lohman, Going, & Howell, 1996). In one study, the original style BIA with applied electrodes was used and still good correlations ($r = 0.88$) were found to computed tomography (CT) (Ryo et al., 2005).

The first non-clinical method involved a lower body analyzer made available for home use in 1992 (Heyward & Wagner, 2004). Leg to leg BIA devices have shown to be more reliable than hand held versions when compared to Air Displacement Plethysmography (ADP) (Peterson, Repovich & Parascand., 2011). Some devices such as the BIA 310 (Biodynamics, Seattle) are portable devices where an electrode is wrapped around the wrist and the ankle, and this method has been validated to ADP, and hydrostatic weighing (HW) (Biaggi et al., 1999). The next method developed by Omron Healthcare, was a handheld upper body BIA device created in the 1990s for home use (Heyward & Wagner, 2004). Various companies that made the lower body analyzers also manufactured full body analyzers where a person stands on electrode plates while holding a handle, which also contain electrodes in each hand, and a segmental BIA (SBIA) reading is given in addition to the whole body composition value. Recently, Tanita has manufactured the BC-418 Segment body composition analyzer (Tanita,

Tokyo, Japan) which is a multi frequency octo-polar model, which has been validated against dual energy x-ray absorptiometry (DEXA) (Pietrobelli et al., 2004). Multi frequency octo-polar models have shown to be in closer agreement to DEXA than single frequency eight electrode models and single frequency four-polar electrode models (Demura, Sato & Kitabayashi., 2004). In one study it was reported that a multi frequency BIA with eight electrodes displayed a difference in which men had an over estimation of percent total body fat and women were underestimated in percent total body fat but there still was not a significant difference between DEXA or hydrostatic weighing (Demura, et al., 2004). It is unclear if there is a sex characteristic or degrees of obesity responsible for the over estimation of body fat percentage in men, and the under estimation of body fat percentage in women from the octopolar model (Demura, et al., 2004).

Being obese or severely obese has been discussed as being a limitation when using BIA, which has consistently overestimated lean body mass in severely obese people (Segal, Loan, Fitzgerald, Hodgdon & Itallie, 1988). This could be due to the fact that impedance is proportional to length and inversely proportional to diameter so a severely obese person who may have more hydration especially in the trunk region due to being obese and is going to have a low impedance reading for the trunk and the total body water may be shown lower than what it really is (Deurenberg, 1996) even though the trunk has been shown to contribute about 10 percent of total impedance for the whole body (Bracco et al., 1996). Over hydration of fat free mass and body shape may be what causes FFM to be overestimated and therefore body fat is than under estimated. As long as a person is in a normal hydrated state for accurate readings, BIA has been effective at estimating total body fatness and segmental body fatness when compared to other clinical

methods (Peterson et al., 2011; Pietrobelli et al., 2004; Ryo et al., 2005). All of these methods rely on the same principles and all are subject to the same validity issues and limitations. BIA like other methods in body composition research has limitations. Quantity and distribution of water within the human body may cause the impedance to change. When a person decides to use a BIA device it is important to be at a normal hydrated state (Heymsfield, Wang, Visser, Gallagher, & Pierson Jr, 1996; Houtkooper, 1996). Exercise may leave a person in a dehydrated state and food intake all have an effect of causing the electrical resistance to be inaccurate, thereby allowing for inaccurate BIA readings (Houtkooper et al., 1996).

Ultrasonography.

The basic technology of ultrasound or ultrasonography requires the human body to be exposed to high-frequency sound waves which in turn, produce an image of the inside of the body. Ultrasound (US) is a relatively new method used in body composition research, and recently a portable US has arrived on the market to measure SAT and VAT (Ulbricht et al., 2012). When comparing results to other body composition measurement tools in a variety of populations, strong correlations were found (Johnson, Naccarato, Corder, & Repovich, 2012; Pineau, & Bocquet, 2009; Ribeiro-Filho, Faria, Azjen, Zanella, & Ferreira, 2003; Rolfe, et. al., 2010; Stolk et al., 2001). Even while on a restricted diet similar results have been reported with adolescents between ultrasound and DEXA after a six-month weight loss program ($r = 0.95$) (Pineau et al., 2010). In addition to measuring body composition, a secondary benefit of US is the ability to measure VAT. The ability of US to assess VAT has been validated against other measurement tools

(Johnson et al., 2012; Ribeiro-Filho et al., 2003; Rolfe, et. al., 2010; Rolfe, et al., 2011; Stolk et al., 2001).

Summary

The obesity epidemic is relevant to the work force and many organizations and companies have started programs to help address the epidemic. Since many organizations are attempting to approach the obesity epidemic, easy to use, reliable and valid methods need to be implemented to measure many people. Clinical assessment methods are not accessible by the public and are expensive. Due to cost and access, field measurements are commonly used to make measurements and estimates of body composition in order to help people identify where they fall in terms of weight and obesity.

Simple field measurements like BMI and WC measurements have been useful due to low cost and efficiency. Ultrasound is available to the public in an affordable form and ultrasound has been shown to be valid in older adults when compared to an MRI. Both men and women with higher waist to hip circumferences have shown stronger associations to encounter CVD even when BMI, cancer and smoking are controlled for. Excessive trunk fat due to obesity is a risk factor for cardiovascular disease and WC is a simple screening tool that can be implemented. Currently, there is no one protocol or WC site that is a standard. WC and ultrasound have not been tested to see if a correlation may exist in visceral fat depth and the various WC sites to help determine if a site may be a better choice over another site.

Chapter 3

Methods

The purpose of this study was to compare waist circumference sites to ultrasound and BIA. Specifically to see if a relationship exist between visceral fat depth from ultrasound and the trunk measure from the BIA to the three different waist circumferences used. This chapter provides a description of the methodology that was used to test the hypotheses for the current study. This chapter provides a background of the participants, information on the instrumentation, an overview of the procedures, and a description of the statistical analyses that will be performed.

Participants

The participants consist of men and women within the ages of 18-55 and were divided by an overweight group with at least a BMI score ≥ 26 kg/m² and an obese group with a BMI score of ≥ 30 . The participants were recruited through flyers and word of mouth from around and in Eastern Washington University and the surrounding community. Table one features descriptive statistics.

Table 1. descriptive Statistics for the entire sample and subgroups.

Variable	ALL n = 72	Men n = 33	Men Overweight n = 16	Men Obese n = 17	Women All n = 39	Women Overweight n = 23	Women Obese n = 16
Age	22.8 ± 5.2	23.6 ± 3.5	23.5 ± 2.8	23.7 ± 4.1	22.2 ± 6.3	20.6 ± 1.4	24.4 ± 9.4
Height (in)	66.2 ± 4.1	70.1 ± 3.1	70.1 ± 3.9	69.9 ± 2.3	64.1 ± 2.5	64.0 ± 2.5	64.2 ± 2.5
Weight (lbs)	202.1 ± 40.6	219.9 ± 28.5	201.8 ± 20.8	237.0 ± 24.1	187.0 ± 43.4	165.4 ± 17.1	218.2 ± 50.9
BMI	31.7 ± 5.7	31.4 ± 3.8	28.5 ± 0.1	34.1 ± 3.6	31.9 ± 6.9	28.3 ± 1.2	37.20 ± 8.2

Instrumentation

The following variables were recorded for each participant in order to conduct this study: age, gender, height, weight, BIA segment analysis of the trunk, ultrasound visceral fat depth, and three standard waist circumference measurements in cm.

Anthropometric measurements of height in inches were taken using a beam scale equipped with a level (Detecto Physician Scale, Cardinal Scale Manufacturing Co., Webb City, MO). Waist circumference was measured using a Gulick tape measure. A multi-frequency BIA (Tanita BC-418 Segmental Body Composition Analyzer) was used for an assessment of % fat in the trunk. Visceral and subcutaneous fat levels were measured with a BodyMetrix (IntelaMetrix, Inc., Livermore, CA) portable ultrasonography machine.

Procedure

After obtaining approval from Eastern Washington University's Institutional Review Board, recruitment started. Testing was administered in the Human Performance Lab. Once the person agreed to be a participant, height and weight were self-reported to find their BMI score, to assure they match the standard body composition of $BMI \geq 26$. Once they were prescreened, they were scheduled for testing. All subjects turned in the signed informed consent at the testing session.

To verify BMI score, height was measured on the stadiometer (Detecto Physician Scale, Cardinal Scale Manufacturing Co., Webb City, MO) Next, BIA trunk fat %, BMI, and body weight in pounds were measured and calculated by the TANITA BC-418. The principle investigator entered the subjects' age, body type (standard for all subjects) and height from stadiometer reading. The subjects were instructed to step onto

the BIA device bare foot, covering the feet plates to have their body composition assessed. When the BIA was set up with the subjects information, the principle investigator instructed the subject to abduct their arms while holding the hand held attachments and covering the metal inserts in the handles, while the reading takes place. After the measurements were made, the subject replaced the handle attachments and stepped off of the BIA device. All body composition data was made available to the subject at the time of testing and after all the data was collected.

Following BIA procedures, the subjects underwent three different waist circumference measurements. Subjects were instructed to have their abdominal area to be accessible for the principle investigator. The first waist circumference measurement was below the lowest palpable rib. The lowest rib was palpated to ensure location of the landmark. Once the landmark was located, the principle investigator wrapped a Gulick tape measure around the subject's abdomen at that level while making sure the tape remained flat all the way around the subject. The tension bar was pulled, the measurement was recorded rounded to the nearest .5cm and recorded on a separate data collection sheet. The procedure was repeated for the second waist circumference measurement taken at the level of the umbilicus. The last waist circumference measurement was taken superior to the iliac crest following the same procedure. After all three waists circumferences were recorded, the principle investigator repeated all three measurements in the same order to ensure reliability. After the second round of measurements, if any site was not within .5cm, additional measurements were taken until two readings were within .5cm, and an average was computed for the final reading used.

The last procedure was an ultrasound scan of the abdomen using the BodyMetrix portable ultrasound device. The Ultrasound gel is used to enhance conduction for the ultrasound wand. To perform the ultrasound reading to assess visceral and subcutaneous fat levels, the gelled wand was placed on the abdomen perpendicular and 1cm to the right side of the umbilicus. Slowly moving the wand 7-10 cm towards the hip completed the abdomen scan. The software included with the BodyMetrix device does not calculate the measurement depths for visceral and subcutaneous fat but the tissue types were visible on the accompanied computer screen. The greatest depth was determined by the principle investigator and recorded on the data sheet.

Analysis

Statistical analysis was performed using SPSS version 23 (SPSS Inc., Chicago, IL). Data was screened for outliers. Descriptive statistics were reported including the subject's age, BMI, BIA, height, VAT, waist circumference sites, and weight. The results are presented in table 1. Pearson's r correlations were used to determine the relationship that exists between the three different waist circumference measurements and BMI, BIA, and ultrasound.

Summary

The purpose of this experiment was to compare waist circumference sites to ultrasound and BIA. Specifically to see if a relationship exist between visceral fat depth from ultrasound and the trunk measure from the BIA to the three different waist circumferences. This chapter presented the methods and statistical analysis used in the study.

Chapter 4

Results

The purpose of this study was to see if a relationship might exist between the visceral fat depth from ultrasound and the trunk measure from the BIA to the three different waist circumferences used. This chapter provides a summary of the results from the statistical analysis depicted in the previous chapter.

Descriptive Statistics

After recruitment 255 people responded. After prescreening only 75 participants completed testing. Three participants did not meet the criteria on day of testing so they were excluded leaving the total sample size to $n = 72$. The means and standard deviations for the descriptive statistics are displayed in Table 1.

Pearson's Correlation

The sample was broken down into overweight ($BMI \geq 26.0 - 29.0$) and obese (≥ 30.0) groups for each gender. Table 2 contains the r values for the entire sample.

Table 2. entire sample r values, $n = 72$.

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.904**	.208	.843*	.166	.253*
WC2	.904**	-	.241*	.862**	.415**	.531**
WC3	.208	.241*	-	.162	.155	.196
BMI	.843**	.862**	.162	-	.418**	.407**
BIA	.166	.415**	.155	.418**	-	.693**
US	.253*	.531**	.196	.407**	.693**	-

* $p < .05$, ** $p < .01$

BMI showed a strong significant correlation to WC1 ($r = .843$, $p = < .01$) and WC2 ($r = .862$, $p = < .01$). BMI had little relationship to WC3. BMI had significant but low correlations to BIA ($r = .418$, $p = < .01$) and US ($r = .407$, $p = < .01$). BIA had a significant but low correlation ($r = .415$, $p = < .01$) to WC2. WC1 and WC3 had no

correlations to BIA. Only WC2 ($r = .531$, $p < .01$) had a significant moderate correlation to ultrasound. The H_0 is rejected for BMI to WC1 and WC2 and accepted for WC3. For BIA the H_0 is rejected for WC2 and accepted for WC1 and WC3. For US the H_0 is rejected for WC1 and WC2 and accepted for WC3. When the sample was than broken down into overweight ($BMI \geq 26.0-29.9$) and obese (≥ 30) groups. Table 3 contains the r values for the overweight group that contains males and females.

Table 3. overweight ($BMI \geq 26.0-29.9$) men and women for the entire sample, $n = 39$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.739**	.754**	.495**	-.876	-.221
WC2	.739**	-	.954**	.571	.251	.350*
WC3	.754**	.954**	-	.534**	.145	.289
BMI	.495**	.571**	.534**	-	.256	.136
BIA	-.187	.251	.145	.256	-	.727**
US	-.221	.350*	.289	.136	.727**	-

* $p < .05$, ** $p < .01$

BMI had a significant but low correlation to WC1 ($r = .495$, $p < .01$) and significant but moderately correlated to WC2 and WC3 sites (WC2 $r = .571$, $p < .01$, WC3 $r = .534$, $p < .01$). BIA showed a significant and high correlation ($r = .727$, $p < .01$) to US. Only WC2 showed a significant but low correlation ($r = .350$, $p < .05$) to US. For BMI the H_0 is rejected for all three WC sites. For BIA the H_0 is accepted for all three WC sites. For US the H_0 is rejected for WC2 and accepted for WC1 and WC3. The BMI and WC 2 should be used together. Table 4 shows the obese group for the entire sample.

Table 4. all obese ($BMI \geq 30$) people of the entire sample, $n = 33$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.879**	.107	.853**	.345*	.240
WC2	.879**	-	.153	.867**	.609**	.518**
WC3	.107	.153	-	.042	.205	.173
BMI	.853**	.867**	.042	-	.640**	.349*
BIA	.345*	.609**	.205	.640**	-	.692**
US	.240	.518**	.173	.349*	.692**	-

* $p < .05$, ** $p < .01$

WC1 ($r = .853$, $p < .01$) and WC2 ($r = .867$, $p < .01$) were the only sites strongly correlated to BMI. BIA had a significant but low correlation ($r = .345$, $p < .05$) to WC1 and WC2 had a significant but moderate correlation ($r = .609$, $p < .01$). US to WC2 had the only correlation and it showed a significant but moderate correlation ($r = .518$, $p < .01$). For BMI the H_0 is rejected for WC1 and WC2 and accepted for WC3. For BIA the H_0 is rejected for WC1 and WC2 and accepted for WC3. For US the H_0 is rejected for WC2 and accepted for WC1 and WC3. Next the data was separated by gender. Table 5 shows the r values for the males as one group.

Table 5. all males, n = 33

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.956**	.956**	.868**	.867**	.686**
WC2	.956**	-	.983**	.858**	.869**	.779**
WC3	.956**	.983**	-	.876**	.857**	.785**
BMI	.868**	.858**	.876*	-	.759**	.669**
BIA	.867**	.869**	.857**	.759**	-	.721**
US	.686**	.779**	.785**	.669**	.721**	-

* $p < .05$, ** $p < .01$

BMI was significant and highly correlated to all three WC sites (WC1 $r = .868$, $p < .01$, WC2 $r = .858$, $p < .01$, WC3 $r = .876$, $p < .01$). All three WC sites (WC1 $r = .867$, $p < .01$, WC2 $r = .869$, $p < .01$, WC3 $r = .857$, $p < .01$) were significantly and highly correlated to the BIA. WC1 ($r = .686$, $p < .01$) had a significant but moderate correlation to US. WC2 ($r = .779$, $p = .01$) and WC3 ($r = .785$, $p < .01$) show significant and highly correlated to US. For BMI, BIA, and US, the H_0 is rejected in all three WC sites. All the males were than broken down into the underweight ($BMI \geq 26-29.9$) category and obese ($BMI \geq 30$) category. Table 6 shows the r values for the overweight category for males only.

Table 6. all overweight ($BMI \geq 26-29.9$) males, $n = 16$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.929**	.951**	.336	.705*	.543*
WC2	.929**	-	.956**	.388	.736**	.673**
WC3	.951**	.956**	-	.324	.742**	.637**
BMI	.336	.388	.324	-	.232	.096
BIA	.705**	.736**	.742**	.232	-	.700
US	.543*	.673**	.637**	.096	.700**	-

* $p < .05$, ** $p < .01$

BMI had no significant and low correlations to all three WC sites. BIA showed a highly significant relationship to all three WC sites (WC1 $r = .705$, $p = < .01$, WC2 $r = .736$, $p = < .01$, WC3 $r = .742$, $p = < .01$). All three WC sites (WC1 $r = .543$, $p = < .01$, WC2 $r = .673$, $p = < .01$, WC3 $r = .637$, $p = < .01$) had significant but moderate correlations to US. For BMI the H_0 is accepted for all three WC sites. For BIA and US the H_0 is rejected for all three WC sites. Table 7 shows the r values for obese ($BMI \geq 30$) males.

Table 7. all obese ($BMI \geq 30$) males, $n = 17$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.930**	.920**	.931**	.900**	.620**
WC2	.930**	-	.986**	.907**	.879*	.760**
WC3	.920**	.986**	-	.893**	.846**	.780**
BMI	.931*	.907**	.893**	-	.866**	.640**
BIA	.900**	.879**	.846**	.866**	-	.692**
US	.620**	.760**	.780**	.640**	.692**	-

* $p < .05$, ** $p < .01$

BMI was high to very highly correlated (WC1 $r = .931$, $p = < .01$, WC2, $r = .907$, $p = < .01$, WC3 $r = .893$, $p = < .01$) to all three WC sites. BIA to WC1 was significant and very highly correlated ($r = .900$, $p = < .01$). WC2 ($r = .879$, $p = < .01$) and WC3 ($r = .846$, $p = < .01$) had significantly high correlations to BIA. Moderate to high significant correlations were found between all three WC sites (WC1 $r = .620$, $p = < .01$, WC2 $r =$

.760, $p < .01$, WC3 $r = .846$, $p < .01$) to US. The H_0 is rejected for BMI, BIA, and US for all three WC sites. Table 8 displays the r values for the females as one group.

Table 8. all females, $n = 39$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.956**	.270	.933**	.516**	.585**
WC2	.956**	-	.257	.879**	.508**	.631**
WC3	.270	.257	-	.150	.106	.178
BMI	.933**	.879**	.150	-	.486**	.415**
BIA	.516**	.508**	.106	.486**	-	.370*
US	.585**	.631**	.178	.415**	.370*	-

* $p < .05$, ** $p < .01$

WC1 ($r = .933$, $p < .01$) and WC2 ($r = .879$, $p < .01$) were significant and very high and highly correlated to BMI. WC1 ($r = .516$, $p < .01$) and WC2 ($r = .508$, $p < .01$) were significant and moderately correlated to BIA. WC1 ($r = .585$, $p < .01$) and WC2 ($r = .631$, $p < .01$) were significant but moderately correlated to US. For BMI, BIA, and US the H_0 is rejected for WC1 and WC2. For BMI, BIA, and US the H_0 is accepted for WC3. BMI with WC1 or WC2 can be used together. Overweight ($BMI \geq 26 - 29.9$) female group r values are presented in table 9.

Table 9. all overweight ($BMI \geq 26-29.9$) females, $n = 23$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.865**	.845**	.740**	.507*	.584**
WC2	.865**	-	.953**	.675**	.420*	.674**
WC3	.845**	.953**	-	.638**	.257	.604**
BMI	.740**	.675**	.638**	-	.546*	.417*
BIA	.507*	.420*	.257	.546**	-	.396
US	.584**	.674*	.604**	.417**	.396	-

* $p < .05$, ** $p < .01$

WC1 ($r = .740$, $p < .01$) showed a significant high correlation to BMI. WC2 ($r = .675$, $p < .01$) and WC3 ($r = .638$, $p < .01$) were significantly but moderately correlated to BMI. WC2 ($r = .420$, $p < .05$) had a significant but low correlation to BIA, while WC1

($r = .507$, $p = < .05$) had a significant but moderate correlation to BIA. All three WC sites (WC1 $r = .584$, $p = < .01$, WC2 $r = .674$, $p = < .01$, WC3 $r = .604$, $p = < .01$) had a significant but moderate correlation to US. For BMI the H_0 is rejected for all three WC sites. For BIA the H_0 is rejected for WC1 and WC2 but accepted for WC3. For US the H_0 is rejected for all three WC sites. Table 10 shows the r values for the obese (BMI ≥ 30) female group.

Table 10. all obese (BMI ≥ 30) females, $n = 16$

Variable	WC1	WC2	WC3	BMI	BIA	US
WC1	-	.943**	.135	.927**	.721**	.305
WC2	.943**	-	.117	.881**	.713**	.312
WC3	.135	.117	-	-.022	.081	.062
BMI	.927**	.881**	-.022	-	.778**	.111
BIA	.721**	.713**	.081	.778**	-	.167
US	.305	.312	.062	.111	.167	-

* $p < .05$, ** $p < .01$

WC1 ($r = .927$, $p = < .01$) was significant and very highly correlated to BMI and WC2 ($r = .881$, $p = < .01$) was significant and highly correlated to BMI. WC1 ($r = .721$, $p = < .01$) and WC2 ($r = .713$, $p = < .01$) were significantly highly correlated to BIA. All three WC sites had non-significant low relationships to US. WC3 had non-significant and low relationship with all variables. For BMI and BIA, the H_0 is rejected for WC1 and WC2 but accepted for WC3. For US the H_0 is accepted for all three WC sites. BMI with WC1 or WC2 can be used together.

Summary

For BMI the sample as an entire group and all the male categories should utilize BMI with WC2. Females as a group or broken down to categories can use BMI with WC1 or WC2.

The sample as one group WC2 was the only site to have a significant moderate relationship to US so WC2 should be used for a group. For males WC2 works with all males, overweight and obese males, but WC3 had a slightly larger correlation to obese males and males as an entire group. For females as a group and as the overweight category, WC2 should be utilized. In the female obese group, there was no significant relationship to any of the variables. WC2 appears to be the best WC measurement overall for this sample.

Chapter 5

Discussion

The main purpose of this study was to see if a relationship existed between the visceral fat depth from an ultrasound measurement and the trunk measure from BIA to the three different waist circumference sites used. This chapter discusses the results from this study as they relate to the current literature.

Results

For the population as a group, WC1 showed no correlation to US which is in disagreement with other authors who claim that WC taken at the lowest palpable rib (WC1) may be best for identifying cardiometabolic disease risk based on VAT deposition patterns (Serviente & Sforzo 2013, Willis et al., 2007). In this study WC just below the lowest palpable rib showed a significant but no correlation ($r = .253, p < .05$) to US and a non-significant ($r = .166$) relationship to BIA. WC2 at the level of the umbilicus had the highest correlation ($r = .862, p < .01$) to BMI and WC2 was the only one of the three sites to have a significant but low correlation ($r = .415, p < .01$) to BIA and a significant but moderate correlation ($r = .531, p < .01$) to US in this sample $n = 72$. WC2 is also not recommended by many organizations such as ACSM, AHA, NHLBI, NIH and the WHO (ACSM, 2010; Cornier et al., 2011; IDF, 2006; NHLBI, 1998; NIH, 2000; WHO, 2008). WC2 was also the only WC site to have a significant but low correlation ($r = .415, p < .01$) to BIA in the same sample $n = 72$. In this study WC just below the lowest palpable rib showed a significant but no correlation ($r = .253, p < .05$) to US and a non-significant ($r = .166$) relationship to BIA.

When the sample is broken down to overweight and obese categories the overweight group for BMI should be paired with WC2 due to having the highest correlation ($r = .571$, $p = < .01$) and again WC2 had the only significant but low correlation ($r = .350$, $p = < .05$) to US. For an overweight population it appears that the level of the umbilicus (WC2) should be used which again is not recommended by a few major organizations. The obese group for BMI also had WC2 being the best match with highest correlation ($r = .867$, $p = < .01$) and BIA ($r = .609$, $p = < .01$) and US $r = .518$, $p = < .01$) as well. BIA also had the most significant but still moderate correlation ($r = .609$, $p = < .01$) to WC2 in the all obese group, which are in a disagreement with Segal et al., 1988 who claim being obese or severely obese is a limitation when using BIA because it consistently overestimated lean body mass in severely obese people. This may still be true for total body fat estimation but for trunk estimation BIA in an obese population had the strongest agreement with US.

The all males group BMI should be paired with superior to the iliac crest (WC3) or WC2, which WC3 is in agreement with ACSM, AHA, and the NIH recommendations. BIA appears to work well in estimating trunk fat percentage at all three WC sites. WC2 (at the level of the umbilicus) and WC3 (superior to the iliac crest) had significant high correlations to US (WC2 $r = .779$, $p = < .01$, WC3 $r = .785$, $p = < .01$) that again agree with ACSM, AHA, and the NIH recommendations in regards to choosing superior to the iliac crest. All three WC sites had moderate significant correlations in the male combined sample (WC1 $r = .686$, $p = < .01$; WC2 $r = .779$, $p = < .01$; WC3 $r = .785$, $p = < .01$). This is in agreement with Kuk et al., 2006 who only had a male sample and CT scans

from Lumbar 1- Lumbar 3 showed the highest correlation ($R^2 = 0.96$, $P < 0.05$) with total volume of fat and lower SEEs than all other images taken by CT scans from T11-S1.

When the all male sample is broken down into overweight and obese categories the overweight category had no significant correlations with any three WC sites but all relationships were low. BMI can be used with any of these three WC sites but note only a low relationship was found. BIA had similar correlations for all three WC sites, which agrees with Segal et al., 1988 whom claim obese or severely obese is a limitation when using BIA and in this overweight sample BIA relationships are similar in all 3 WC sites. WC2 and US had the strongest and significant correlation (WC2 $r = .736$, $p = < .01$) so WC2 is recommended for overweight males. For obese males BIA had a very high and significant correlation to WC1 ($r = .900$, $p = < .01$) and high correlations to WC2 ($r = .879$, $p = < .01$) and WC3 ($r = .846$, $p = < .01$). These results are in disagreement with Segal et al., 1988 who claim being obese or severely obese is a limitation when using BIA because it has consistently overestimated lean body mass in severely obese people. For a dominant male sample maybe a lower WC measurement would be better. This could be due to males tending to develop android obesity.

The all female group also had WC2 having the highest significant moderate ($r = .631$, $p = < .01$) correlation to US.

WC3 superior to the iliac crest had no significant relationship to BIA, BMI or US. This was the lowest WC measurement so it may be that measuring too low on the torso may show no relationship to actual VAT. As a group sample mixed with males and females, this study suggests using the WC site at the level of the umbilicus.

In the male only samples, both groups overweight and obese BMI found WC2 having the highest US correlation with WC3 next followed by WC1. The correlation with BIA was highly significant in all male groups with obese with WC1 having the highest correlation ($r = .900$, $p = < .01$) in this study which agrees with Willis et al., 2007 who claim that the lowest palpable rib may be best for identifying cardiometabolic disease risk based on VAT. These results are in disagreement with Segal et al., 1988 who claim being obese or severely obese is a limitation when using BIA because it has consistently overestimated lean body mass in severely obese people. For a dominant male sample maybe a lower WC measurement would be better. This could be due to males tending to develop android obesity.

In the all female group only WC1 and WC2 had relationships to BMI, BIA or US. WC3 had no significant relationship to any of the variables as a group. BMI should be paired with WC1 due to the significant and high correlation ($r = .933$, $p = < .01$) to BMI. WC3 had no relationship to BIA or US for the all female group so its possible that higher WC sites may be more useful in this population. This could be due to the way females store fat. WC at the umbilicus (WC2) had the strongest significant but moderate correlation ($r = .631$, $p = < .01$) to US. When the females were broken down into the overweight and obese BMI, BMI and WC1 continued to have the strongest correlations ($r = .740$, $p = < .01$) and BIA ($r = .507$, $p = < .05$). However, for US, WC2 had the strongest and significant relationship ($r = .674$, $p = < .01$). The obese group for females WC1 had the highest and significant relationships to BMI ($r = .927$, $p = < .01$) and BIA ($r = .721$, $p = < .01$) while US had no relationship to any of the WC sites. This could be due to body fat distribution being a gynoid type.

Future Research directions

Future research should include a larger sample size with age and possibly ethnicity as additional variables to see if the correlations are strengthened or weakened. This research only included the three main WC sites so midway between the lowest rib and the iliac crest and minimal waist should be investigated as well. The gender difference in the present study suggests future research to determine if different WC sites should be researched for males and females. For men it appears as weight is gained lower WC sites should be used. Overweight and obese males had stronger relationships at the lowest WC site used. Studies looking at overweight and especially obese females should look into below the lowest palpable rib; midpoint between the lowest rib and the iliac crest and minimal waist to see what relationships may exist. It is possible for this group that higher up on the torso maybe better to use. This study also combined all levels of obesity into a single group. Since US found no relationship to any site it is possible that the different levels of obesity in males and females need to be conducted to see what kind of relationships may exist.

Conclusion

The results of this study show that WC at the level of the umbilicus (WC2) with or without BMI is recommended for this college student sample of males and females ages 18-55 years old, due to the relationships with BMI, BIA and US that were observed. There was a gender effect and males may require lower WC sites and females may require higher WC sites. This gender effect may possibly be due to body fat distribution differences. To add to or strengthen these results, it seems worthy to conduct a larger scale study to include the various levels of obesity with all five WC sites and to also

include ethnicity as well. This chapter presented a discussion of the results and how they relate to the current literature. This research is a step forward towards providing a standard for a WC protocol.

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Appendix 1: IRB Approval

To: Austin Nelson, Department of Physical Education, Health and Recreation,
200PEB

From: Sarah Keller, Chair, Institutional Review Board for Human Subjects
Research

Date: December 31, 2015

Subject: Expedited IRB Review of *Determining the Relationship Between Three
Waist Circumference Measures, BIA, Trunk Percent Fat, and Ultrasound
Abdominal Fat Depth* (HS-4936)

The Institutional Review Board for Human Subjects' Expedited Review Committee has reviewed your proposal to see if there is a correlation between any of the three main WC sites and either US or BIA.

The Committee has approved your proposal; a signed, approved copy of your application is enclosed.

Human subjects research approval granted by the IRB is valid for one year from the date of approval, to December 31, 2016. If research is to continue, with no substantial changes, beyond that date, a renewal of IRB approval must be obtained prior to continuation of the project (contact OGRD for procedure). If, subsequent to initial approval, a research protocol requires minor changes, the OGRD should be notified of those changes. Any major departures from the original proposal must be approved by the appropriate review process before the protocol may be altered. A Change of Protocol application must be submitted to the IRB for any substantial change in the protocol. The Director, Grant and Research Development, or the Chair of the IRB will determine whether or not the research must then be resubmitted for approval.

If you have additional questions please contact me at 359-7039; fax 359-2474; email: skeller@ewu.edu. It would be helpful if you would refer to HS-4936 if there were further correspondence as we file everything under this number. Thank you.

cc: C.Brewer
R.Galm
W.Repovich
Graduate Office

Appendix 2: Informed Consent

Informed consent form

“Determining the relationship between three waist circumference measures, BIA trunk percent fat, and ultrasound abdominal fat depth”

In partial fulfillment of Master’s Thesis for Austin Nelson

Principal Investigator

Austin Nelson

1110 E. Cozza Dr Spokane, WA 99208
253-250-1219

ausnelson@comcast.net

Responsible Project Investigator

Wendy Repovich, Ph.D., FACSM

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Purpose and Benefits

Obesity and being overweight have several health implications such as risk for type 2 diabetes, cardiovascular disease, hypertension, high cholesterol, and certain forms of cancer that result in premature death. Various methods have been used to assess risk, but there has been no standardization of measurement of the waist circumference. Identifying obese and overweight people is important. The purpose of this study is to determine the relationship between any of the three main waist circumference sites, ultrasound measures of abdominal fat depths and Bioelectrical Impedance measure of trunk percent fat to recommend a preferred measurement location.

Procedures

You will come to the Human Performance Lab at Eastern Washington University where the following measurements will be taken. You will need to wear clothing that will allow measurements of the abdomen.

- 1) Your height and weight will be measured using a physician’s scale with a stadiometer to determine BMI.
- 2) Your waist circumference will be measured at three sites using a Gulick measuring tape. The sites are superior to the iliac crest, level of the umbilicus, and right below the lowest palpable rib.
- 3) The body fat percentage of your abdomen will be measured using bioelectrical impedance analysis on a machine (resembling a scale) that uses a measure of electrical impedance to estimate % body fat of the trunk.
- 4) Your total, visceral, and subcutaneous fat depths will be measured by an ultrasound machine. A dime-sized amount of ultrasound gel will be placed on the wand which will then be placed on the abdomen to the right of the umbilicus and the scan will be performed by moving the wand 7-10 cm across the skin toward the right hip.

Risk, Stress or Discomfort

There is minimal risk of an allergic reaction to the ultrasound gel. All equipment will be cleaned before and after each use. Body composition results may cause some stress for individuals. Lifestyle counseling will be available for my benefit at the time of the measurements if needed.

Inquiries

Any questions about the procedures used in this study are encouraged. If you have any concerns, questions, or would like more information please contact Wendy Repovich or Austin Nelson prior to signing the informed consent form. We can be reached at (509)359-7960; wrepovich@ewu.edu and (253) 250-1219 ausnelson@comcast.net respectively.

Other Information

If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protection Administrator, (509) 359-6567 or rgalm@ewu.edu

Signature of Principal Investigator

Date

Subject Statement

My participation in this study is completely voluntary. I am free to refuse participation and to stop at any point in this study. I understand the study procedures that I will perform, and the possible risks that go along with the testing and training. Knowing all of the risks and discomforts, and being allowed to ask questions that have been answered to my satisfaction, I consent to take part in this study. I am not waiving my legal rights by signing this form. I understand I will receive a signed copy of this consent form.

Signature of Participant

Date

Appendix 3:

Data Collection Sheet

Name

Male or Female (circle)

Height

Weight

BMI score

BIA % trunk fat

WC site 1 _____ 2 _____ 3 _____

Ultrasound VAT depth –

Notes -

Vitae

Author:

Austin M. Nelson

Birthplace:

Tacoma, Washington

Undergraduate Schools Attended:

Eastern Washington University, Cheney, WA
Bachelor of Science, Exercise Science, 2011

Honors and awards:

Graduate Assistantship, Physical Education, Health and Recreation Department
Eastern Washington University, 2011-2013
Graduated Magna Cum Laude, Eastern Washington University, Summer 2011

Professional Experience:

Strength and Conditioning internship – Football and Men’s Basketball, Eastern
Washington University, Cheney, WA: Summer 2011