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COMPARING BODY COMPOSITION METHODS FOR BOWLING GREEN STATE UNIVERSITY’S AIR FORCE ROTC PROGRAM

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Table of Contents

Abstract

In special populations, such as ROTC cadets, body composition is used not only as a predictor of fitness, but also for additional purposes such as qualification for enlistment, load carriage, and duty fulfillment (Johnson et al., 2019). There is great concern that the circumference-based equations used to classify cadets may misclassify service members of more muscular builds as being overweight (Grier et al., 2015). The purpose of this study was to compare multiple body composition methods, including the military's method of circumference-based measurement, in order to identify a suitable method for Bowling Green State University's Air Force ROTC program. Participants were recruited from the Air Force ROTC Detachment 620 at Bowling Green State University {N = 24; Male, n = 21; Female, n= 3}. Anthropometric (height and weight) and body composition measurements (air displacement plethysmography (ADP), bioelectrical impedance analysis (BIA), skinfolds, and circumferences) were collected for each participant in the Exercise Physiology Lab at Bowling Green State University. A repeated measure analysis of variance (ANOVA) was used to compare body composition measurement methods. A significant difference between skinfolds and BIA occurred (p=0.025). Using the BMI and circumference compliant/non-compliant scale listed in the AFI guidelines, a greater number of cadets fell into the non-compliant category according to BMI (n=7) versus circumferences (n=1). The findings from this investigation suggest that the circumference-based method can appropriately provide accurate body composition results amongst ROTC cadets. Results also determined that the military's circumference-based method underestimated body fat compared to the "gold standard" ADP, however these differences were not considered statistically significant. Further research should be conducted to identify body composition

methods and/or techniques that are easy to implement and provide accurate body composition outcomes at the individual level.

Comparing Body Composition Methods for Bowling Green State University's Air Force ROTC Program

Body composition is an aspect of health that military cadets, specifically Reserve Officer Training Corps (ROTC), must maintain throughout their time in the service. Body composition can be an important predictor of health because excess fat mass may be linked to chronic disease and poor physical performance (Steed et al., 2016). There are multiple methods used to assess body composition including skinfold measurement, bioelectrical impedance analysis (BIA), height and circumference measurement, and air-displacement plethysmography (ADP). In special populations, such as ROTC cadets, body composition is used not only as a predictor of fitness, but for additional purposes such as qualification for enlistment, load carriage, and duty fulfillment (Johnson et al., 2019), therefore it is important that the method of measuring body composition in all ROTC cadets is accurate.

The U.S. Department of Defense (DOD) confirms that body composition is a useful measurement for assessing the health of cadets. "In 1981, the DOD mandated that each branch of the military develop and implement its own body composition analysis (BCA) program tailored to its specific mission" (Latour et al., 2019, p. 92). Over the past couple of decades, Schuna et al. (2013) reported that there have been a number of circumference-based body composition prediction equations that the DOD has developed and distributed to the different branches of the U.S. Armed Forces. "The primary purpose of fitness and body composition standards in the military has always been to select individuals best suited for the physical demands of military service based on the assumption that proper body weight supports good health, physical readiness, and appropriate military appearance" (Naghii, 2006, p. 550). "The physical fitness and health of U.S. military personnel is viewed as a key component of their operational effectiveness, combat readiness, and day-to-day functioning ability" (Schuna et al., 2013, p .188).

Although body fat standards vary among the different branches of the U.S. military, all military personnel, regardless of branch of service, are subject to circumference measurements either as an initial evaluation or when their maximum weight exceeds the DOD guidelines (Babcock et al., 2006). Personnel exceeding threshold values of body weight based upon their height measurement are typically further evaluated using a circumference-based method that is used to predict the cadets' percent body fat (Schuna et al., 2013). Pierce et al. (2017) described that these percent body fat results are rated in specific categories (i.e., compliant and non-compliant) and thresholds for these categories are based on sex. However, cadets who do not exceed threshold values of body weight based upon their height are not further evaluated using circumference measurements. Steed et al. (2016) highlighted the cost effectiveness and practicality of the height and circumference method which is likely most convenient for military usage; however, military research tends to challenge the validity of these measurements (Schuna et al., 2013).

Although several researchers have investigated the effectiveness of circumference-based equations compared with other body fat assessment methods, the ability of the circumference-based equation method to accurately and reliably estimate body fat percentages of all military personnel is an on-going concern (Babcock et al., 2006). Babcock et al. (2016) explains how the limited training required of military personnel to use a tape measure has certainly been an influential factor in maintaining the use of the current methodology. Schuna and colleagues (2013) concur with these findings and also suggest that circumference-based assessments appear to provide reasonable body composition estimates at the group level; however, the individual level of variability of this measurement could be rather high in the cases of some cadets. Concern arises when the circumference-based equation method misclassifies service members of more muscular builds as being overweight (Grier et al., 2015). Military personnel who fail to meet these body composition standards may be penalized by being denied specific positions or promotions or risk being relieved from all military duties (Schuna et al., 2013). Babcock and colleagues (2016) concluded that any military branch is vulnerable to a greater number of cadets who will be misclassified as non-compliant when using the circumference-based method. Although the circumference-based method offers a quick and noninvasive option for assessing body composition, this method is of limited use if falsely classifying cadets into non-compliant categories. In order to differentiate and accurately assess the components that constitute body composition, other methods of measuring body composition that provide greater accuracy should be explored.

The components that comprise an individual's body composition include fat-free mass (FFM), fat mass (FM), total body water (TBW), fat-free dry mass (FFDM) and bone mineral density (BMD). The methods used to measure these components are substantially different than circumference-based methods, leading one to scrutinize whether circumference-based methods provide reasonable estimates of body composition (Malina & Geithner, 2011). In addition, Grumstup & Lukaski (1992) agree that the body composition standards for military service members are rigid and demand peak fitness. "Presently, the available anthropometric techniques for estimating percent body fat in the U.S. military are not valid for assessing body composition of individual service members" (Grumstup & Lukaski, 1992, pg. 192). Therefore, the investigation and conclusion that the U.S. military's method for estimating percent body fat is not valid has proposed the idea that a further detailed assessment using other methods of measuring body composition should be conducted.

Researchers suggest that the method used by the United States military to measure body composition of military personnel is inaccurate and lacks validity (Schuna et al., 2013). Furthermore, military personnel who are misclassified using the circumference-based method may face disciplinary action. Therefore, the current method of measuring body composition has left a gap that challenges researchers to find a valid method of measuring body composition deemed suitable for the military population, specifically the ROTC. Thus, the purpose of this study is to compare multiple body composition methods, including the military’s method of circumference-based measurements, in order to identify a suitable method for Bowling Green State University’s Air Force ROTC program.

Literature Review

Body Composition Background

Body composition has been considered the precedent in creating a connectable foundation between health and fitness. The study of modern human body composition is over 100 years old, spanning disciplines like clinical nutrition, sport and exercise science, and medicine (Coufalova et al., 2019). Body composition can also be used as a tool for risk assessment or as a measure of change in exercise or diet (Vasold et al., 2019). For ROTC cadets, maintaining a healthy body composition is not only important as an indicator of health, but also as a measure of fitness in predicting the ability to carry out necessary tasks required by the military.

The models and components of body composition mentioned in Malina & Geithner's (2011) study offer insight into the different methods of measuring body composition with greater precision and sensitivity. FM is basic to all models and methods, whereas; depending on level of analysis, FFM can be divided into the two primary components that are solid and liquid (Malina & Geithner, 2011). The various methods available for assessing body composition are based on two-compartment (2C), three-compartment (3C), four compartment (4C) or multi-compartment models (Kuriyan, 2018). Kuriyan (2018) mentions that the simplest approach in measuring body composition is the 2C model, which divides body weight into FM and FFM (Kuriyan, 2018). This model is followed up by the 3C model which adds in a third component that divides FFM into lean tissue mass (LTM) and bone mineral content (BMC) (Kuriyan, 2018). The last model, also known as the 4C model, of measuring body composition is obtained by combining many methods to divide body mass into fat, mineral, TBM, and protein (Kuriyan, 2018). Of these four models that were investigated by Kuriyan (2018), it was concluded that the 4C model is considered to be the criterion method for measuring body composition, and therefore it is important to consider both accuracy and precision when comparing models and methods. Nevertheless, it is essential to factor in which method of assessing body composition is most pragmatic based on feasibility, cost, technician skill, and time needed.

Skinfolds

The skinfold method is based on the principle that there is a correlation between subcutaneous body fat, otherwise known as skinfold thickness, and total body fat (Aandstad et al., 2014). Skinfold measurements from specific anatomical sites can be used to predict body density (BD), from which FFM or percent body fat (%BF) can then be calculated using one of the various types of equations (Aandstad et al., 2014). Babcock and colleagues (2006) collaborated to compare the validity between the military circumference equation method to skinfold-based equations. The authors of this study did not have access to a group of military cadets and suggested that male firefighters were the best available population that mimicked the physical demands of a military cadet. The researchers measured the subjects' body circumference and skinfolds to determine if there was a relationship between circumference-based measurements and skinfold-based measurements. Results of this study suggested that a greater BF% was estimated in non-compliant personnel using the circumference-based equation in comparison to the skinfold-based equation. Based on the results of this study, the authors concluded that when military circumference-based equations are used to predict BF%, a greater number of subjects are likely to be classified as non-compliant than when using the skinfold-based equation (Babcock et al., 2006).

While skinfolds may be a preferred alternative method of measuring body composition for military cadets, factors such as measurement technique, and technician experience may threaten the accuracy of results while using this method. Hydration, sex, age, and ethnicity are other elements that can alter results (Barreira et al., 2013). Furthermore, measuring compressed tissue or double layers of skin might reduce the precision and accuracy of these results (Tafeit et al., 2015). The skinfold method is vulnerable to a variety of factors that may alter the validity of this method, however there are some advantages noted within the literature that deem this method suitable for usage amongst military personnel.

A few advantages of the skinfold technique are its reliability and validity, relative ease of administration, and its cost effectiveness compared to methods such as BIA, hydrodensitometry, and ADP (Babcock et al., 2006). Shafer et al. (2010) agreed with this statement and suggest that although the skinfold method relies on a logarithmic relationship between skinfold thickness and BF to estimate BD, this method is practical and cost effective. Skinfold measurements provide a simple, easy, and quick yet highly informative assessment of body fatness in most subjects (Wells & Fewtrell, 2006). Thus, this is the reason why skinfold thicknesses are commonly measured in clinical and field settings (Peterson et al., 2003).

Other methods of measuring body composition, such as BIA, hydrodensitometry, and ADP challenge elements such as practicality and reliability, which may be deemed unsuitable for the purpose of measuring body composition in military cadets. Research findings suggest that the skinfold method can be a reliable technique that should be considered for use in measuring body composition in military cadets (Babcock et al., 2006). However, it is recommended that other methods be explored to test reliability and validity.

Bioelectrical Impedance Analysis

BIA measures the impedance (the alternating current analog to resistance) of a small electrical current that advances through the water in both muscle and fat (Carrion et al., 2019).

Currently, limited research investigating the accuracy of BIA measurements in military cadets exists. However, Langer and associates (2018) investigated the accuracy of prediction equations based on BIA with regard to changes in FFM in male Army cadets. FFM was calculated using eight different BIA prediction equations in these Army cadets (n=310). Dual-Energy X-ray Absorptiometry (DXA) was used as a reference method in this study to compare values in fat-free mass. Statistical analyses were run to determine the accuracy of BIA prediction equations in estimating Army cadet’s FFM. Researchers discovered that the eight BIA prediction equations were not found to be valid when analyzing FFM changes in Army cadets (Langer et al., 2018). Based on the results of this study, Langer et al. (2018) concluded that other methods of measuring body composition should be considered when measuring body composition amongst military cadets.

Mullie et al. (2008) were interested in determining whether BMI classifies cadets into a similar category as BIA. The researchers used a random sample of 448 male military candidates between the ages of 18 and 20 years who were selected based on their initial medical visit to a military recruitment center. The participants’ BF% was measured using BIA. BMI was calculated by dividing weight in kilograms by height in meters squared (kg/m^2). Participants were then they were classified into specific categories based on their results. Participants with a BF% of under 20.9% were considered normal weight, while participants with a BF% of over 21% were classified as overweight. Categories for BMI included underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), and overweight (25.0-29.9 kg/m^2). The results of this study suggested that the differences in classification between BMI and BIA were statistically different. It was determined that 372 out of the 448 participants were correctly classified into the same categories for both BMI and BIA. Researchers concluded that although it would be preferable to utilize the BIA method for body composition assessment in military candidates, using the BIA approach is too time-consuming, in comparison to the current military's method, considering the high number of military candidates that enlist every year.

Another drawback of BIA that was noted in the literature is that there is a variety of elements that can challenge the validity of this method. Aleixo et al. (2019) mentions that BIA devices can produce different results based on the prediction equations that are programmed within the device along with the frequencies of alternating currents. Additionally, adequacy of tissue hydration of the participant also influences the outcome of results. "Dehydration is another element that can affect BIA outcomes because it increases the body's electrical resistance and, in some cases, has shown to cause as much as a 5 kg underestimation of fat-free mass" (Carrion et al., 2019 p. 325). Other elements mentioned by Langer et al. (2018) that might alter body composition outcomes in BIA include age, sex, disease, and ethnicity; however, the BIA method does offer some advantages for usage.

"While the accuracy of BIA in assessing the percentage of FM and hydration status has been recently questioned, BIA has been shown to correctly detect differences in absolute values for FM and FFM, as well as detect TBW variations" (Campa et al., 2020 p. 362). In addition, Aleixo et al. (2019) suggests that highly skilled personnel are not required for administering a BIA measurement and with every measurement the results are readily available. Thus, the practicality and portability, as well as the relative inexpensiveness of this method are beneficial when considering BIA for body composition measurement. Although some drawbacks were mentioned with BIA, this method may be considered to assess body composition as opposed to other methods for military usage (Mullie et al., 2008). However, most literature suggest that the validity of the BIA method should be further explored, and future research is preferred.

Air Displacement Plethysmography (ADP)

ADP is a body composition assessment method that uses air displacement to measure FM and FFM. Currently, the only commercially available system for ADP is the BodPod® (Fields et al., 2002). "The ADP method is a 2C model (FM and FFM), in which BD is calculated from mass and volume, with volume measured by air displacement" (Merrigan et al., 2018 p. 1146). Biaggi et al. (1999) conducted a comparison study between three methods of measuring body composition that included ADP, BIA, and hydrodensitometry. Biaggi and colleagues (1999) wanted to compare measurements of BF% in healthy adults using all three techniques to determine which technique would be proposed as the most accurate. The sample in this study consisted of men (n =23) and women (n =24) who were considered healthy. All of the participants BF% was measured using all three techniques and then analyzed using a two-way ANOVA to examine differences between methods and sexes. The findings within this research study suggested that in comparison to hydrodensitometry (the gold standard), ADP underestimated BF% in men but overestimated BF% in women indicating that the differences between sexes were statistically significant. Therefore, the findings of this study suggest that ADP should be considered an acceptable method for assessing body composition (Biaggi et al., 1999). Although this method determines BF% to an acceptable degree of accuracy, factors other than reliability and validity such as expense and availability of the equipment also need to be considered in order to make this technique suitable for populations such as the military.

In order to justify the long-term use of ADP in any population, factors such as validity and reproducibility should be established (Hillier et al., 2014). "To mitigate any erroneous data, the BodPod® manufacturers recommend that testing should be conducted prior to exercise, the subject should be dry, and that the testing environment remain stable" (Fields et al. 2004 p. 3).

Michels et al. (2012) adjoined to the constraints of this method and reported that logistic and budgetary restrictions can force this method to be difficult to use, especially in large studies. However, the BodPod® tends to be used as the reference method because it is validated against other methods of measuring body composition, such as BIA and skinfolds, and is referenced as the gold standard (Foucart et al. 2017).

ADP offers several advantages over other established methods including a quick, comfortable, automated, non-invasive, and safe measurement process (Fields et al., 2002). In addition, ADP has been considered to display high reliability and validity for the evaluation of body composition in a variety of subject types and populations (Vasold et al., 2019). With applicability to the military population, ADP has provided reliable and valid measurement changes of body composition in healthy young men who are engaged in military training (Malavolti et al., 2018). Malavolti and colleagues (2018) conducted a study that was designed to examine the effects of intense military training on body composition in three separate phases. Body composition changes were assessed using three different techniques which included skinfolds, ADP, and DXA. BMI was also calculated in this study. Twenty-seven young men from the Italian military made up the participants of this study. Skinfolds, ADP, and DXA were all collected for each subject. A Pearson correlation was conducted to compute the differences between each method. “At any visit, FFM and FM correlation measured by ADP and DXA was significantly greater than that measured by SF” (Malavolti et al., 2018, p.506). The study also discovered a significant difference in BMI before and after the study. Therefore, it was concluded in this study that ADP or DXA estimates of FM and FFM should be the preferred method over skinfolds when detecting changes in body composition amongst military cadets.

Similar research completed by Dave (2015) also analyzed three body composition methods. The purpose of this study was to compare the standard anthropometric assessments of ROTC cadets using tape measurements to ADP and skinfolds. Thirteen ROTC cadets were recruited from local universities in Ohio. Descriptive statistics were then generated to classify each cadet based on Air Force standards. The results suggested that the skinfolds tended to overestimate body fat while the tape measurement underestimated body fat. However, data from the ADP assessment suggested that all the participants were either classified as “lean” or “moderately lean” (Dave, 2015). Aside from the skinfolds and the standard tape method used by the military, it was concluded that ADP should be used to measure body composition in ROTC cadets as the two other methods tended to underestimate or overestimate body fat (Dave, 2015).

Based on these research studies, it can be concluded that the ADP method is considered to be the “gold standard” and should be the preferred method when assessing body composition in military populations. Reliability and validity in ADP were proven in cadaver analysis when ADP was compared to a multi-compartment model. “The closest science can get to cadaver analysis is the multi-compartment model and percent fat results obtained from ADP have not been shown to be statistically different than results from multi-compartment models” (COSMED, 2021, pg.3). BodPod® is a piece of equipment that is immobile and challenges budgetary restrictions, although if ROTC programs have access to such equipment, they should consider using this method of body composition testing as its applicability and reliability have proven valid compared to other methods of body composition measurement.

Anthropometric Measurements (BMI)

For several decades, body mass index (BMI) has been a useful metric used to diagnose obesity in individuals (Jitnarin et al., 2014). BMI is a value that is derived from the height and mass of an individual. Values greater than 25 and 30 are considered to classify an individual as overweight and obese, respectively (Malavolti et al., 2008). As Ode et al. (2006) reports, BMI has been used amongst the general population as a predictor of morbidity and mortality. Mullie and colleagues (2018) support this claim and suggest that overweight and obesity are associated with increased risk for diabetes, hyperlipidemia, coronary heart disease, and other respiratory or cardiac issues (Mullie et al. 2008). In specific populations such as the military, where there is a demand for physical fitness and superior health, BMI is taken very seriously as this is a representation of health and physical performance capabilities (Friedl, 2012). That being said, military personnel are unlike the average population due to the demand for high physical performance and health, therefore using BMI as a predictor of body fat for these individuals has raised concerns.

Ode and associates (2006) challenged this method using a group of athletes who replicate the military population because of the high demands for physical performance. The primary purpose of this study was to describe the relationship between BMI and percent body fat, and to determine the accuracy of BMI as a predictor of percent body fat in college athletes and nonathletes. The participants in this study included 226 college aged athletes and 213 college aged non-athletes. Three male groups were assembled: 1) non-athletes, 2) football lineman, and 3) athletes. Two female groups were formed including 1) non-athletes, and 2) athletes. BMI was calculated for each subject and body fat percentage was determined via ADP. The results suggested that the sensitivity of the analysis was very high in male athletes and non-athletes, as well as female athletes. The researchers concluded that there is a need for different BMI classifications of overweight, specifically for populations such as athletes. Wellens et al. (1996) also suggest that the only reason that BMI is criticized as an indicator of health is because the weight of the individual does not decipher between muscle, fat, or bone and therefore, an individual who may carry high FFM could produce a high BMI value. As a consequence of this misleading measurement, many muscular or high FFM individuals are misclassified as overweight instead of normal (Mullie et al., 2008). This could be very dangerous or threatening to military members as they may be labeled as non-compliant, thus leading to disciplinary action or discharge from military services. Therefore, it is vital to understand the validity and accuracy of BMI as a predictor of body fatness in special populations such as the military. However, as mentioned by Grier et al. (2015), the Center for Disease Control and Prevention, the World Health Organization, and the National Heart, Lung, and Blood Institute, actually endorse or recommend BMI as a screening tool for assessing body weight.

"One of the primary advantages of using BMI in population research is not only its centrality to key biological pathways leading to crucial health outcomes, but also that it is relatively straight forward to measure" (Chernenko et al., 2019 p. 2). Another key advantage of using BMI as a method of measuring body composition is that the measures needed for calculation – height and weight – are simple measurements and can be taken with precision and high accuracy (Tuttle et al., 2016). However, the practicality and application of BMI as an accurate measure of body fatness for the military population is still a concern that many researchers have yet to find an alternative. Grier and associates (2015) decided to take this challenge head on with a research study questioning if BMI misclassifies physically active young men, however BMI thresholds were adjusted to fit age and gender rather than height and weight. Therefore, the primary purpose of this study was to determine the accuracy of age and gender adjusted BMI as a predictor of body fat in U.S. Army Soldiers. Researchers collected data on roughly 110 soldiers who had a mean age of 23, an average BMI of 26.4 and an average BF% of

18. BMI was calculated using height and weight while BF% was determined using DEXA. A linear regression was then used to determine if there was any correlation between BMI and BF%. The findings suggested that in specific populations where physical fitness and training are requirements of duty, adjusting BMI cutoff values to fit age and gender rather than height and weight would provide reasonable assessment outcomes. In addition, there was a strong correlation between BMI and body fat percentage (Grier et al., 2015).

To add to the findings of this study, as well as the advantages of BMI, this method is considered to be ideal because of little to no cost, minimal training for the operator, and exact precision while collecting measurements (Gupta et al., 2014). There has been tremendous discourse discussing the advantages and disadvantages of this method, specifically for use in populations such as the military. BMI could be a very effective tool for predicting body fatness in the military population because of the minimal training, inexpensiveness, and precision measurements. However, there is still a great deal of concern that this method tends to misclassify military personnel due to the unaccountability of FFM and unreliable outcomes. Individuals who use this method should do so with caution if trying to determine accurate body composition measurements in military cadets.

Conclusion

"The physical fitness and health of U.S. military personnel is viewed as a key component of their operational effectiveness, combat readiness, and day-to-day functioning ability" (Schuna et al., 2013 p. 188). The primary purpose of fitness and body composition standards in the military has always been to select individuals who are best suited to meet the physical demands of military service (Naghii, 2006). Body composition standards have been in use by military services as early as the 1980's as a prevention method for obesity and to promote good fitness habits (Friedl et al., 2002). Excess body weight in military personnel raise a high level of concern for health and performance (Naghii, 2006). It is because of this level of concern that U.S military personnel are required to comply with body composition standards (Steed et al., 2016). “Thus, sufficient levels of physical fitness are emphasized in military personnel due to the high physical demands during military training and warfare” (Mackey & DeFreitas, 2019 p. 2). Military applicants who fail to meet fitness requirements, along with body composition standards, may be subjected to disciplinary action (Babcock et al., 2006).

Methods

Participants

Participants were recruited from the Air Force ROTC Detachment 620 at Bowling Green State University {N = 24; Male, n = 21; Female, n= 3}. Participants were initially informed of the study by word of mouth during an organized ROTC physical training (PT) session. Individuals who were interested in participating were asked to sign-up to attend an informative session in the Exercise Physiology Lab at Bowling Green State University. Inclusion criteria for participation included (a) currently enrolled in Air Force ROTC Detachment 620; (b) completed an Air Force Personal Fitness Test (AFPFT) within 3 months of participation in the study; (c) at least 18 years of age; (d) do not have an implanted medical device. Individuals who voluntarily agreed to participate in the study were asked to sign an informed consent document after procedures of the study were discussed and all questions were answered. Participants were informed that they may discontinue participation in the study at any time. University Institutional Review Board (IRB) approval was established to ensure that the design of this study protected the rights of the participants.

Procedures

Anthropometric (height and weight) and body composition measurements (ADP, BIA, skinfolds, and circumferences) were collected for each participant in the Exercise Physiology Lab at Bowling Green State University. Measurements were taken in the following order: height, weight from the BodPod scale, ADP, BIA, skinfolds, and circumference measurements. All participants were instructed to refrain from any strenuous exercise, eating, or drinking at least 2-3 hours prior to testing. Participants were instructed to wear normal physical test clothing to the Exercise Physiology Lab and change into body composition specific attire per measurement. Clothing and accessories such as shoes, socks, jewelry, and hair accessories were instructed to be removed before any measurements were conducted. These instructions were in accordance with the AFI 36-2905 guidelines set forth by the United States Air Force for body composition testing (AFI, 2013).

Anthropometric Measurements

Anthropometric measurements collected included height (in) and weight (lb). Height was measured using a stadiometer (Seca 213; Hamburg, Germany). Participants were instructed to stand upright with their head straight, heels together, and back touching the stadiometer. The measuring level was then lowered to the top of the participant's head and the measurement was recorded to the nearest tenth of an inch. Weight was recorded using the value obtained from the BodPod scale (COSMED; Rome, Italy). Participants were instructed to stand on the scale and stay as still as possible until the BodPod indicated that the measurement had been recorded. Weight was measured to the nearest tenth of a pound. BMI was calculated by dividing the participant's mass in kilograms by height in meters squared (kg/m^2).

Body Composition Measurements

Air Displacement Plethysmography (BodPod). The BodPod (COSMED; Rome, Italy) was calibrated prior to data collection to ensure an accurate measurement of body density. Prior to the measurement, participants were instructed to change into specific clothing (compression shorts for both male and female participants, a swim cap, and a sports bra for females) and remove jewelry, glasses, watches, socks, and shoes as recommended by COSMED. Body mass was measured using an electronic scale that was linked to the BodPod. Participants then entered the BodPod and were instructed to sit on the bench as still as possible and to breathe normally throughout the assessment. Participants completed two test trials, each lasting 45 seconds. If the results of the first two measurements were not within 0.2%, a third measurement was taken. Body density was converted to a body fat percentage using the Siri equation (Siri, 1961).

Bioelectrical Impedance Analysis. The InBody 230 (Biospace Co.; Seoul, Korea) was used to assess body composition via bioelectrical impedance. Before testing, participants were instructed to remove shoes and socks. Participants were then instructed to step on the InBody scale and align their feet with the platform electrodes in order to measure weight. Once the InBody confirmed the participant's weight, demographic information such as height, age, and sex were input into the system. Participants were instructed to grab the handles of the InBody and place their thumbs on the oval electrodes. While doing so, participants were also instructed to keep their arms straight and away from the body. Participants were informed to stay as still as possible until the test was completed. The results of the test were displayed on the InBody and recorded.

Skinfolds. Lange calipers (Beta Technology; Ann Arbor, Michigan) were used to collect skinfold measurements. Skinfold measurements were taken at the following seven sites: abdomen, triceps, thigh, chest, axilla, subscapular, and suprailiac (ACSM, 2018). Each measurement was completed three times using a rotating circuit method and taken only on the right side of the body. Measurements were recorded to the nearest millimeter. If measurements at a site were greater than 3mm different, a fourth measurement was taken and the outlier measurement was discarded.

Table 1
Skinfold Description

ABDOMEN	Vertical fold; 2 cm to the right side of the umbilicus
TRICEPS	Vertical fold; on the posterior midline of the upper arm, halfway between the acromion and the olecranon processes, with the arm held freely to the side of the body
THIGH	Vertical fold; on the anterior aspect of the thigh; halfway between the midpoint of the inguinal ligament and the proximal border of the patella

CHEST	Diagonal fold; one-half the distance between the anterior axillary line and the nipple (Males), or one-third of the distance between the anterior axillary line and the nipple (Females)
AXILLA	Vertical fold; on the midaxillary line at the level of xiphoid process of the sternum, an alternate method is a horizontal fold taken at the level of the xiphoid/sternal border in the midaxillary line
SUBSCAPULAR	Diagonal fold; 1-2 cm below the inferior angle of the scapula
SUPRAILIAC	Diagonal fold; in line with the natural angle of the iliac crest taken in the anterior axillary line immediately superior to the iliac crest

Table 1 Adapted from: (ACSM, 2018)

Circumferences. Circumference measurements were recorded to the nearest tenth of an inch using a Gulick tape to imitate the Air Force's method of measuring circumferences. Circumference measurement sites for male cadets included neck and waist, while the circumference measurement sites for female cadets included neck, waist, and hip (AFI, 2013). Neck circumferences were measured at the mid-neck point between the mid-cervical spine and mid-anterior aspect of the neck below the laryngeal prominence for males. Neck circumferences for females were measured at the point just below the larynx. Waist circumferences were measured at the smallest circumference point below the rib cage and above the umbilicus for male and female cadets. Hip circumferences were measured around the greatest protrusion of the buttocks for female cadets.

Statistical Analyses

IBM SPSS Statistics Version 27 (IBM Corp., Armonk, N.Y., USA) was used to complete all statistical analyses. Means and standard deviations for age, height, weight, BMI, ADP, BIA, skinfolds, and circumference measurements were calculated using descriptive statistics. A repeated measure analysis of variance (ANOVA) was used to compare body composition measurement methods. The Bonferroni adjustment was utilized for multiple comparisons. Sex was a between participant variable (Male Air Force Cadets, Female Air Force Cadets). The level of significance was set prior to analysis at $p < 0.05$.

BMI and circumference results were displayed as a percentage of compliance according to the AFI guidelines (Table 6; AFI, 2013). ADP was used as the “gold standard” of comparison for body composition.

Results

Twenty-four participants {Male, n=21; Female n=3} completed the study. Means and standard deviations for age, height, weight, and BMI are listed in Table 2. Means and standard deviations for each body composition method are listed in Table 3.

Table 2
Descriptive Statistics for Participants' (n=24) Demographics

Variables	*Mean ± SD*	*Minimum*	*Maximum*
Age (years)	20.3 ± 1.08	19.0	23.0
Height (inches)	69.7 ± 3.59	61.5	76.5
Weight (lbs.)	162.4 ± 27.4	114.96	231.96
BMI (kg/m^2)	23.3 ± 2.72	18.3	29.0

Note: SD (Standard Deviation)

Table 3
Descriptive Statistics for Participants' (n=24) Body Composition

Body Composition Methods	*Mean ± SD*	*Minimum*	*Maximum*
ADP %	14.27 ± 5.37	5.0	25.0
BIA %	15.96 ± 6.71	6.8	36.6
Skinfolds %	11.17 ± 4.41	5.8	21.5
Circumferences %	12.54 ± 5.83	5.0	32.0

Table 4 displays the results of the one-way ANOVA used to compare the body composition methods. A significant difference between groups (*p*=0.025) was identified. Table 5 includes the multiple comparisons between body composition methods. A significant difference between skinfolds and BIA occurred (*p*=0.025). There was no significant difference identified between other methods of body composition.

Table 4
One-Way ANOVA – Between/Within Groups

Between/Within Groups	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	311.713	3	103.904	3.260	.025*
Within Groups	2932.385	92	31.874		
Total	3244.097	95			

**Significant at p < 0.05*

Table 5
Post Hoc Tests – Bonferroni

Body Fat	*Body Fat*	*Mean Difference*	*Std. Error*	*Sig.*	*95% LB*	*95% UB*
ADP	Circ.	1.733	1.62977	1.00	-2.6613	6.1280
	BIA	-1.68750	1.62977	1.00	-6.0822	2.7072
	SF	3.1000	1.62977	.362	-1.2947	7.4947
BIA	Circ.	3.42083	1.62977	.231	-.9738	7.8155
	ADP	1.68750	1.62977	1.00	-2.7072	6.0822
	SF	4.78750	1.62977	.025*	.3928	9.1822
SF	Circ.	-1.36667	1.62977	1.00	-5.7613	3.0280
	ADP	-3.1000	1.62977	.362	-7.4947	1.2947
	BIA	-4.78750	1.62977	.025*	-9.1822	-.3928
Circ.	ADP	-1.733	1.62977	1.00	-6.1280	2.6613
	BIA	-3.42083	1.62977	.231	-7.8155	.9738
	SF	1.3667	1.62977	1.00	-3.0280	5.7613

**Significant at* $p < 0.05$

Circ = Circumferences, ADP = Air Displacement Plethysmography, BIA = Bioelectrical Impedance Analysis, SF = Skinfolds

Participants were classified by the BMI and circumference compliant/non-compliant scale listed in the AFI guidelines (Table 6; AFI, 2013). Compliant and non-compliant classifications differed based on sex. Male cadets were considered non-compliant with a body fat percentage over 18% while female cadets were considered non-compliant with a body fat percentage over 24% (AFI, 2013). Using ADP as the ‘gold standard” of body composition comparison, twenty-two participants fell into the compliant category while two fell into the non-compliant category (91.7% and 8.3%, respectively).

Table 6

Compliant/Non-Compliant – BMI & Circumferences

BMI/Body Composition Method	*Compliant*	*Non-Compliant*
Body Mass Index (BMI)	70% (n=17)	30% (n=7)
Circumferences	95% (n=23)	5% (n=1)

Discussion

There has been a growing debate over the validity and reliability of the military's method of measuring body composition amongst cadets. Over the past couple of decades, numerous circumference-based body composition prediction equations have been developed by the DOD and distributed to the different branches of the U.S. Armed Forces (Schuna et al., 2013). Although body fat standards vary among the different branches of the U.S. military, all military personnel, regardless of branch of service, are subject to circumference measurements either as an initial evaluation or when their maximum weight exceeds the DOD guidelines (Babcock et al., 2006). In branches of the military where body weight is evaluated as an initial measure, cadets who exceed threshold values of body weight based upon their height are considered "non-compliant" and are further evaluated using circumference measurements. Although several researchers have investigated the effectiveness of these circumference-based equations compared with other body fat assessment methods, the ability of the circumference-based equation method to accurately and reliably estimate body fat percentages of all military personnel is an on-going concern (Babcock et al., 2006). The current method is considered to be cost effective and convenient, however, there is concern that the military's circumference-based method could misclassify service members (Grier et al., 2015; Steed et al., 2016). This current method of measuring body composition in the U.S. military has left a gap that challenges researchers to find a valid method of measuring body composition deemed suitable for the military population, specifically the ROTC.

When comparing the results produced by several methods of measuring body composition (ADP, BIA, skinfolds, circumferences), the researchers of the current study discovered that there was a statistically significant difference between skinfolds and BIA.

Explanations for these differences may include error associated with skinfold measurements, and/or hydration status associated with the BIA method. Heyward & Wagner (2004) suggest that even when technicians use appropriate technique, predicting percent body fat from skinfolds can be approximately ± 3.5% different from gold standards. Other factors that may have contributed to error associated with skinfold measurements could include poor anatomical landmark identification by the researcher or the extreme leanness of the subjects being measured (Heyward & Gibson, 2014). Bioelectrical impedance has been shown to either overestimate or underestimate fat-mass when participants are dehydrated or overhydrated, respectively (Flakoll et al., 2004). Saunders et al. (1998) also suggests that there is high variability with BIA when hydration status is altered. Ultimately, there could have been a few explanations associated with either the skinfold method or the BIA method that suggest why the results were statistically significantly different.

The researchers of this study additionally concluded that the military's circumference-based method underestimated body fat compared to the "gold standard" ADP, however these differences were not considered statistically significant. Prior research by Schuna et al. (2013) found a similar result in which the DOD equation underestimated percent body fat and fat mass changes in comparison to ADP. A study conducted by Dave (2015) determined that circumference measurements showed the highest variability and also underestimated percent body fat when comparing results from circumference measurements to ADP in ROTC cadets. The trend of the military's circumference method underestimating body fat in participants in comparison to ADP as the gold standard, provides supportive evidence as to why the findings in this study may have occurred the way they did.

Body mass index was not considered a method of body composition but was calculated to classify participants using the compliant/non-compliant standards listed in the AFI guidelines (AFI, 2013). According to BMI standards, seven participants were non-compliant (BMI >25 kg/m^2). However, of these seven participants who were considered non-compliant per BMI standards, only one participant was classified as non-compliant using the circumference standards. These results could be due to the fact that BMI does not distinguish between fat-mass and fat-free mass. A study completed by Steed et al. (2016) similarly found that BMI does not directly correlate with the results of the military's circumference-based method, specifically in ROTC cadets. Because of these results, cadets who are not compliant based on BMI standards, should have body composition measured to determine good standing health. Babcock et al. (2006) also mentions that BMI should not be used as a substitute for body composition assessment in the U.S. military as their results suggested that individuals of average weight were classified as overweight when using BMI. Ultimately, the military's circumference-based method may be an appropriate method for assessing body composition amongst ROTC cadets based on the fact that there were no significant differences in circumference results in comparison to results of the other methods, especially the "gold standard" ADP method. Factors such as practicality, portability, and low-cost are what make the military's circumference-based method efficient to use.

Strengths

A strength of this study was the inclusion of multiple methods of measuring body composition. The opportunity to compare the military's circumference method to several body composition methods was ideal especially for future researchers who wish to compare all of these methods of measuring body composition to the military's circumference method. An additional strength of this study was the accessibility of the population being studied. Unlike some universities, Bowling Green State Univeristy has an Air Force ROTC program on campus, therefore the population was easily accessible.

Another strength of this study was the participants' familiarity with the concept and measurement of body composition. All of the participants were familiar with the military's circumference method and some were also familiar with the skinfold method. This could be a major reason as to why some of the participants may not have been as apprehensive to participate in this study. Lastly, a final strength of this study was the design of the data collection. Participants were instructed to attend only one session to collect data, therefore participants only needed to report the Exercise Physiology Lab once and did not need to follow up for further testing.

Limitations

There were several limitations that should be noted for this study. First, since the population of interest was the Air Force ROTC Detachment 620 at Bowling Green State Univeristy, the pool of potential participants started small. Of the 51 available ROTC cadets within the program, a total of 24 participated in this study, therefore these results may not be directly applicable to a larger population. In addition, there were a low number of female participants (*n*=3) in comparison to male participants (*n*=21). Furthermore, the sample was fairly homogenous (Caucasian males), thus the results are not generalizable to a diverse population. Another limitation may be present in the population being investigated. It is expected that all ROTC cadets maintain not only physical, but height and weight standards throughout their tenure within the program. The majority of the cadets in this study were already considered to be in good health and physical shape. This limitation could be a major reason for the mean body fat percentages being low amongst all four body composition methods and the low number of non-compliant participants. A final limitation of this study is the "healthy user" effect. The participants in this study were knowledgeable about their body composition and compliant/non-compliant status prior to participating in this study due to periodical body composition assessments with the military. It is possible that cadets who were previously compliant may have participated in this study, while cadets who previously fell into the non-compliant category may not have participated due to the possibility of receiving a non-compliant result again.

Practical Application & Implications

The findings of this study draw attention to the underestimation of percent body fat in the military's method of circumference-based measurements. Further research needs to be conducted on the different methods of measuring body composition in order to determine a suitable method of measuring body composition amongst ROTC cadets.

Future Research

Moving forward, researchers should approach the military's method of circumference-based measurements with caution. Although there were no significant differences surrounding the military's method of measuring body composition, the military's circumference method did underestimate body fat compared to the "gold standard" of ADP. Future research should be conducted using a larger sample size and include more women ROTC cadets. Other branches of the military (i.e. Army, Marines, & Navy) should also be considered for participation in future research to compare the results of circumference-based measurements to their body composition standards. Future research is needed to further analyze the results of circumference-based measurements.

Conclusions

In conclusion, the findings from this investigation are in consensus with previous work that determined that the circumference-based method can appropriately provide accurate body composition results amongst ROTC cadets (Steed et al., 2016). However, ROTC cadets, as well as military personnel, need to be aware of the underestimation that the circumference-based measurements may produce when assessing body composition. Although circumference-based measurements might be efficient for use in larger populations, ROTC programs should evaluate other methods of measuring body composition to best fit the needs of individual cadets. Further research should be conducted to identify body composition methods and/or techniques that could be easy to implement and provide accurate body composition outcomes at the individual level.

References

Aandstad, A., Holtberget, K., Hageberg, R., Holme I., & Anderssen, S.A. (2014). Validity and reliability of bioelectrical impedance analysis and skinfold thickness in predicting body fat in military personnel. *Military Medicine, 179*(2), 208-217.

Air Force Instruction (AFI) 36-2905. *Fitness Program*, 21 October 2013.

Aleixo, G.F.P., Shachar, S.S., Nyrop, K.A., Muss, H.B., Battaglini, C.L., & Williams, G.R. (2019). Bioelectrical impedance analysis for the assessment of sarcopenia in patients with cancer: A systematic review. *The Oncologist, 25*(2).

American College of Sports Medicine (2018). ACSM's resources for the exercise physiologist: A practical guide for health and fitness professional. Wolters & Kluwer.

Babcock, C.J., Kirby, T.E., McCarroll, M.L., & Devor, S.T. (2006). A comparison of military circumference equations to skinfold-based equations to estimate body composition. *Military Medicine, 171*(1), 60-63.

Barreira, T.V., Renfrow, M.S., Tseh, W., & Kang, M. (2013). The validity of 7-site skinfold measurements taken by exercise science students. *International Journal of Exercise Science, 6*(1), 20-28.

Biaggi, R.R., Vollman, M.W., Nies, M.A., Brener, C.E., Flakoll, P.J., Levenhagen, D.K., Sun, M., Karabulut, Z., & Chen, K.Y. (1999). Comparison of air-displacement plethysmography with hydrostatic weighing and bioelectrical impedance analysis for the assessment of body composition in healthy adults. *The American Journal of Clinical Nutrition, 69*(5), 898-903.

Campa, F., Matias, C.N., Marini, E., Heymsfield, S.B., Tosellli, S., Sardinha, L.B., & Silva, A.M. (2019). Identifying athlete body fluid changes during a competitive season with bioelectrical impedance vector analysis. *International Journal of Sports Physiology Performance, 15*(3), 361-367.

Carrion, B.M., Wells, A., Mayhew, J.L., & Koch, A.J. (2019). Concordance among bioelectrical impedance analysis measures of percent body fat in athletic young adults. *International Journal of Exercise Science, 12*(4), 324-331.

Chernenko, A., Meeks, H., & Smith, K.R. (2019). Examining validity of body mass index calculated using height and weight data from the US driver license. *BMC Public Health, 19*(100), 1-11.

Coufalova, K., Komarc, M., & Cochrane, D.J. (2019). Comparison of bioelectrical impedance analysis and air displacement plethysmography. *International Journal of Morphology, 37*(3), 985-990.

COSMED (2021). Multi-compartment model (MCM) and body composition measurement techniques. https://www.cosmed.com/hires/WP_Multi_compartment_model_EN.pdf

Dave, N.J. (2015). Body composition of reserve officers training corps (ROTC) cadets: A comparison across three techniques of measurement. Wright State University, Dayton, Ohio.

Fields, D.A., Goran, M.I., & McCrory, M.A. (2002). Body-composition assessment via air-displacement in adults and children: A review. *American Journal of Clinical Nutrition, 75*, 453-467.

Fields, D.A., Higgins, P.B., & Hunter, G.R. (2004). Assessment of body composition by air-displacement plethysmography: Influence of body temperature and moisture. *Dynamic Medicine, 3*, 1-7.

Flakoll, P.J., Kent, P., Neyra, R., Levenhagen, D., Chen, K.Y., & Ikizler, T.A. (2004). Bioelectrical impedance vs air displacement plethysmography and dual-energy X-ray absorptiometry to determine body composition in patients with end-stage renal disease. *Journal of Parenteral and Enteral Nutrition*, *28*(1), 13-21.

Foucart, L., De Decker, A., Sioen, I., De Henauw, S., & Michels, N. (2017). Hand-to-foot bioelectrical impedance analysis to measure fat mass in healthy children: A comparison with air-displacement plethysmography. *Nutrition and Dietetics, 74,* 516-520.

Friedl, K.E., & Leu, J.R. (2002). Body fat standards and individual readiness in a randomized Army sample: Screening weights, methods of fat assessment, and linkage to physical fitness. *Military Medicine, 167,* 994-1000.

Friedl, K.E. (2012). Body composition and military performance – Many things to many people. *Journal of Strength and Conditioning Research, 26*(7), 87-100.

Grier, T., Chervak, M.C., Sharp, M., & Jones, B.H. (2015). Does body mass index misclassify physically active young men. *Preventative Medicine Reports, 2,* 483-487.

Grumstup-Scott, J., & Marriott, B.M. (1992). Body composition and physical performance: Applications for the military services. National Academies Press.

Gupta, S., & Kapoor, S. (2014). Body adiposity index: Its relevance and validity in assessing body fatness of adults. *ISRN Obesity, 2014*, 1-5.

Heyward, V.H., & Gibson, A. (2014). *Advanced fitness assessment and exercise prescription.* (7th ed). Human Kinetics.

Heyward, V.H. & Wagner, D. (2004). *Applied body composition assessment*. (2nd ed). Human Kinetics.

Hillier, S.E., Beck, L., Petropoulou, A., & Clegg, M.E. (2014). A comparison of body composition measurement techniques. *Journal of Human Nutrition and Dietetics, 27*, 626-631.

IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.

Jitnarin, N., Poston, W.S.C., Haddok, C.K., Jahnke, S.A., & Day, R.S. (2014). Accuracy of body mass index – defined obesity status in US firefighters. *Safety and Health at Work, 5*(2014), 161-164.

Johnson, Q.R., Mackey, C.S., Muddle, T.D., Smith, D.B., & DeFreitas, J.M. (2019). Body composition comparison of upper- and underclass reserve officers training corps cadets. *Aerospace Medicine and Human Performance, 90*(9), 814-818.

Kuriyan, R. (2018). Body composition techniques. *Indian Journal of Medicine Research, 148*, 648-658.

Langer, R.D., Matias, C.N., Borges, J.H., Cirolini, V.X., Pascoa, M.A., Guerra-Junior, G., & Goncalves, E.M. (2018). Accuracy of bioelectrical impedance analysis in estimated longitudinal fat-free mass changes in male army cadets. *Military Medicine, 183*(7), 324-331.

Latour, A.W., Peterson, D.D., & Riner, D.D. (2019). Comparing alternate percent body fat estimation techniques for United States navy body composition assessment. *International Journal of Kinesiology in Higher Education, 3*(4), 93-105.

Mackey, C.S., & DeFreitas, J.M. (2019). A longitudinal analysis of the U.S. air force reserve officers training corps physical fitness assessment. *Military Medicine Research, 6*(30), 1-8.

Malavolti, M., Battistini, N.C., Manfredo, D., Bruno, B., Bagni, I., & Pietrobelli, A. (2008). Effect of intense military training on body composition. *Journal of Strength and Conditioning Research, 22*(2), 503-508.

Malina, R.M., & Geithner, C.A. (2011). Body composition of young athletes. *American Journal of Lifestyle Medicine, 5*(3), 262-278.

Merrigan, J.J., Gallo, S., Field, J.B., & Jones, M.T. (2018). Foot-to-foot bioelectrical impedance, air displacement plethysmography, and dual x-ray absorptiometry in resistance-trained men and women. *International Journal of Exercise Science, 11*(4), 1145-1155.

Michels, N., Huybrechts, I., Bammann, K., Lissner, L., Moreno, L., Peeters, M., Sioen, I., Vanaelst, B., Vyncke, K., & De Henauw, S. (2012). Caucasian children's fat mass: Routine anthropometry versus air-displacement plethysmography. *British Journal of Nutrition, 109*(8), 1528-1537.

Mullie, P., Vansant, G., Hulens, M., Clarys, P., & DeGrave, E. (2018). Evaluation of body fat estimated from body mass index and impedance in Belgian male military candidates: Comparing two methods for estimating body composition. *Military Medicine, 173*(3), 266-270.

Naghii, M.R. (2006). The importance of body weight and weight management for military personnel. *Military Medicine, 171*(6), 550-555.

Ode, J.J., Pivarnik, J.M., Reeves, M.J., & Knous, J.L. (2007). Body mass index as a predictor of percent fat in college athletes and nonathletes. *Medicine & Science in Sports & Exercise, 39*(3), 403-409.

Peterson, M.J., Czerwinski, S.A., & Siervogel, R.M. (2003). Development and validation of skinfold-thickness prediction equations with a 4-compartment model. *The American Journal of Clinical Nutrition, 77*(5), 1186-1191.

Pierce, J.R., DeGroot, D.W., Grier, T.L., Hauret, K.G., Nindl, B.C., East, W.B., McGurk, M.S., & Jones, B.H. (2017). Body mass index predicts selected physical fitness attributes but is not associated with performance on military relevant tasks U.S. Army soldiers. *Journal of Science and Medicine, 20*, 79-84.

Saunders, M.J., Blevins, J.E., & Broeder, C.E. (1998). Effects of hydration changes on bioelectrical impedance in endurance trained individuals. *Medicine & Science in Sports & Exercise, 30*(6), 885-892.

Schuna, J.M., Hilgers-Greterman, S.J., Manikowske, T.L., Tucker, J.M., & Liguori, G. (2013). The evaluation of a circumference-based prediction equation to assess body composition changes in men. *International Journal of Exercise Science, 6*(3), 188-198.

Shafer, K.J., Siders, W.A., Johnson, L.K., & Lukaski, H.C. (2010). Body density estimates from upper-body skinfold thicknesses compared to air displacement plethysmography. *Clinical Nutrition, 29*(2), 249-254.

Siri, W.E. (1961). *Body composition from fluid space and density: techniques for measuring body composition*. In J. Brozek & A. Hanschel (Eds.), (pp. 223-244). Washington, DC: National Academy of Science.

Steed, C.L., Krull, B.R., Morgan, A.L., Tucker, R.M., & Ludy, M.J. (2016). Relationship between body fat and physical fitness in Army ROTC cadets. *Military Medicine, 181*(9), 1007-1012.

Tafeit, E., Kaimbacher, P.S., Wallner-Liebmann, S.J., Reibnegger, G., Cvirn, G., Jurimae, J., Saar, M., Maestu, J., Purge, P., Latt, E., & Jurimae, T. (2015). Caliper versus lipometer – comparing two methods of subcutaneous body fat measurement by Bland-Altman diagrams. *Collegium Antropologicum, 39(*3), 611-615.

Tuttle, M.S., Alexander, M., & Kaminsky, L. (2016). The benefits of body mass index and waist circumference in the assessment of health risk. *ACSM's Health & Fitness Journal, 20*(4), 15-20.

Vasold, K.L., Parks, A.C., Phelan, D.M.L., Pontifex, M.B., & Pivarnik, J.M. (2019). Reliability and validity of commercially available low-cost bioelectrical impedance analysis. *International Journal of Sport Nutrition and Exercise Metabolism, 29*(4), 406-410.

Wellens, R.I., Roche, A.F., Khamis, H.J., Jackson, A.S., Pollock, M.L., & Siervogel, R.M. (1996). Relationships between the body mass index and body composition. *Obesity Research, 4*(1), 35-44.

Wells, J.C.K., & Fewtrell, M.S. (2006). Measuring body composition. *Archives of Disease in Childhood, 91*(7), 612-617.

Appendices
Appendix A

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BOWLING GREEN STATE UNIVERSITY
School of Human Movement, Sport, and Leisure Studies

Informed Consent Form

Project Title: *Comparison of Body Composition Methods for Bowling Green State University's Air Force ROTC Program*

Researcher: Trey Naylor, Graduate Student, Kinesiology

Introduction: My name is Trey Naylor and I am a kinesiology graduate student working under the supervision of Dr. Jessica Kiss, Assistant Teaching Professor at Bowling Green State University. I am inviting you to participate in a research study.

Purpose and Benefits: The purpose of this study is to compare multiple body composition methods, including the military's method of circumference-based measurements, in order to identify a suitable alternative method for Bowling Green State University's Air Force ROTC program. The benefits of the study to you include receiving body composition results from multiple methods. You can then compare the results from the methods tested to your results from the military's method.

Procedures: Your total participation time in an informative session and the testing sessions should take approximately 90 minutes (informative session: 30 minutes, one testing (measuring) session: 60 minutes).

You will: 1) schedule a time for the testing session in the Exercise Physiology Laboratory (Eppler South, Room 124) at Bowling Green State University; 2) wear appropriate clothing for the different tests (height, weight, air displacement plethysmography, bioelectrical impedance, skinfolds, circumferences); 3) sign off on measurements to validate results. After you have read this consent form, you can agree to participate or not. If you wish not to participate, we will thank you for your time and efforts to assist us, and you may leave the lab.

The informative session will take approximately 30 minutes. The session is to familiarize you with the study procedures surrounding body composition and to answer any questions that you may have about the study.

For the testing session, after height and weight data are collected, the body composition measurement methods will be administered. The body composition measurement methods include air displacement plethysmography, bioelectrical impedance, skinfolds, and circumference.

1. ***Height & Weight***

a. Height will be measured to the nearest tenth of an inch using a stadiometer (*Seca – Germany*). Participants will be instructed to stand upright with heels together, head straight, and back touching the stadiometer while being measured. The measuring level will then be lowered to the top of the participant's head and the measurement will be recorded. Weight will be measured using the scale from BodPod. Body Mass Index (BMI - kg/m^2) is calculated using the measurements recorded for height and weight.

2. Air Displacement Plethysmography

a. The *BodPod* (*COSMED – Rome, Italy*) will be calibrated at the beginning of the testing session to ensure an accurate measurement of body density. Data such as height and weight are needed before administering the test. Participants' body mass will be assessed using an electronic scale that is linked to the BodPod. Height will be measured using a calibrated stadiometer. Once data are entered, participants will then be fitted with a swim cap. Participants then will enter the BodPod and complete two trials lasting 45 seconds each. Participants will be instructed to remain still and breathe normally while inside the BodPod. Body density will be calculated via internal *BodPod* software and converted to a body fat percentage using the Siri equation.

3. Bioelectrical Impedance Analysis

a. The InBody 230 (Biospace Co. – Seoul, Korea) will be used to assess body composition using bioelectrical impedance. Participants will be instructed to remove their shoes and socks and step onto the InBody scale and align their feet with the electrodes. This will measurement the participant's weight. When the participant's weight is confirmed, demographic information such as height, age, and sex will be inputted into the InBody. Participants will then be instructed to grab the handles of the InBody and place their thumbs on the oval electrodes while also keeping their arms straight and away from the body. Participants will be instructed to stay as still as possible until the test is completed.

4. Skinfolds

a. Lange calipers (*Beta Technology – Ann Arbor, Michigan*) will be used to collect skinfold measurements. Skinfold measurements will be taken on the right side of the body in circuit rotation at seven different sites. Sites include chest, triceps, abdomen, suprailiac, axilla, thigh, and subscapula. Each measurement will be taken three times. Measurements will be rounded to the nearest millimeter. If a measurement difference of greater than 3mm appears, then a fourth measurement will be taken while the outlier measurement is discarded.

5. Circumference Measurements

a. Circumference measurements will be recorded to the nearest tenth of an inch with a Gulick tape. All measurements are taken three times and the average of three measurements will be used for data recording and analysis

Voluntary nature: Your participation in this study is completely voluntary. You are free to withdraw at any time. You may decide to not do a particular task or discontinue participation at any time without penalty. You must be 18 years of age or older to participate. Deciding to participate or not will not affect your relationship with Bowling Green State University, the BGSU Air Force ROTC, with Mr. Naylor, Dr. Kiss, or anyone involved in the research.
Confidentiality Protection: Your information will remain confidential. Your information will be stored in individual folders which will be locked in an office in Eppler Complex. All information will be typed into a program on a password-protected computer. The hard copy of the consent form will be kept in your folder in a locked cabinet. Only the researchers and their research assistants working directly on the study will have access to the data. You will create an ID# and this will be used to specify your information during the study and in subsequent analyses and publications.

Risks: The risks of participation in this study are minimal (i.e., no greater than those experienced in everyday life).

In the very unlikely event that you do experience a problem or injury occurs, seek medical treatment. The cost of such treatment will be at your expense. The researcher is First Aid and CPR/AED certified, and will be monitoring you throughout the testing. If you have any problems following the testing, you should contact myself or Dr. Kiss with questions or concerns.

Contact information: If you have any questions about this research study or your participation in the testing please contact me, Trey Naylor, work: 937-638-5638, treyn@bgsu.edu , Dr. Kiss, work: 419-372-0027, jekiss@bgsu.edu. You may also contact the Chair of the Institutional Review Board at 419-372-7716 or orc@bgsu.edu, if you have any questions about your rights as a participant in this testing.

Statement of Consent

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. A copy of this form will be provided to me.

__________________________________   ____________________
Printed Name   Date

____
Participant Signature

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Appendix B

Data Sheet

Participant ID Code: ____

1) HEIGHT & WEIGHT:

Height: ___________ in.

Weight: ___________ lb.

2) BODPOD:

% Body Fat: __________ %

Fat Mass: _________ lbs

Fat-Free Mass: ________ lbs

3) INBODY MEASUREMENT:

SMM: _________

FAT: __________

TBW: _________

PBF: __________

4) CIRCUMFERENCE MEASUREMENTS:

Male

Neck Circumference: _______ in

Waist Circumference: ________ in

Female

Neck Circumference: _______ in

Waist Circumference: ________ in

Hip Circumference: ________ in

SKINFOLD MEASUREMENTS:

Skinfold Measures (mm) At a given site, measures must agree within 3 mm

		3 Measures		**Median**
1. Abdomen	a. ____________	____________	____________	____________
2. Axilla	a. ____________	____________	____________	____________
3. Chest	a. ____________	____________	____________	____________
4.Subscapula	a. ____________	____________	____________	____________
5. Suprailiac	a. ____________	____________	____________	____________
6. Thigh	a. ____________	____________	____________	____________
7. Triceps	a. ____________	____________	____________	____________

TEST ADMINISTRATOR

x___________________________

PARTICIPANT

x___________________________

Appendix C

Informative Session Sign-Up

BGSU EMAIL