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Agreement in the Army's Circumference Measurements and Dual-Energy X-Ray Absorptiometry

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AGREEMENT IN THE ARMY'S CIRCUMFERENCE

MEASUREMENTS AND DUAL-ENERGY X-RAY

ABSORPTIOMETRY

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ABSTRACT

AGREEMENT IN THE ARMY'S CIRCUMFERENCE MEASUREMENTS AND DUAL-ENERGY X-RAY ABSORPTIOMETRY

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The United States military has two primary outcomes for fitness: combat readiness and physical appearance. In response to the Army Weight Control Program, height-weight tables were put forth to evaluate soldiers' body fat percentages and screen for overweight individuals. However, few studies have examined the agreement in body composition estimates between the Army's circumference measurements and dual-energy x-ray absorptiometry (DXA). The purpose of this study was to quantify the agreement in body fat percentage estimates between the Army's circumference measurements and dual-energy x-ray absorptiometry in male Army Reserve Officers' Training Corps (R.O.T.C.) cadets. Male R.O.T.C. cadets (N = 23) between the ages of 18-24 from Central Washington University's R.O.T.C. program were used as participants. Participants underwent taping according to Army protocol, and a DXA test to examine percentage body fat. Utilizing SPSS, a modified Bland-Altman (BA) plot was used to analyze the quality of agreement for continuous variables. There was a significant negative correlation between the difference in percentage body fat (taping – DXA) and the DXA scores (r = -0.722, $p < 0.001$), indicating poor agreement between the taping field test and the DXA laboratory criterion. The results depict little methodological agreement in percentage body fat between taping and the DXA. In contrast, when

analyzing the categorical variables, overweight and over-fat, there is a moderate level of agreement between the height-weight tables and DXA methods as demonstrated by the 78.3% percent of agreement.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

The United States military has two primary outcomes for fitness: combat readiness and physical appearance. Therefore, when the Army Weight Control Program (AWCP) was created in the early 1980s, its fundamental principle encompassed military bearing (good physical appearance) with health concerns being secondary outcomes (19). In response to the AWCP, height-weight tables (Appendix A) were put forth to evaluate soldiers' body fat percentages and screen for overweight individuals (19). Height-weight tables compare height and age values to provide a maximum weight requirement. Those exceeding the allowed body weight are then circumference measured, colloquially known as "taped," to determine body fat percentage (Appendix B) (5). Circumference measuring is beneficial as it differentiates those who are overweight due to high muscle mass. If individuals are over-fat, they are placed in a weight control program to improve physical appearance (17).

As military bearing is imperative for career advancement, it is crucial to examine the methods with which physical appearance is being tested (6,10,16). Consequentially, previous studies have examined the validity of the military's circumference equations using techniques such as skinfolds, bioelectrical impedance (BIA), underwater weighing (UWW) and dual-energy X-ray absorptiometry (DXA) and found both agreement (16,17) and disagreement (6,23,29).

Literature Review

History of the Army's Taping Method

The United States military has been regulating soldiers' weight for entry into the force, as well as to maintain military status, for hundreds of years. However, throughout the years the standards have evolved and fluctuated according to the needs of the country. It has been suggested that individuals who are stronger, in better physical shape, and are of sound mind will be able to perform their jobs more competently (22).

Over time, the requirements for body composition have shifted dramatically. In 1808, the first recorded physical fitness standards were put in place by the military. These requirements solely included being physically healthy and to preferably be from the country, therefore signifying strength to carry large loads and endure weather fluctuations. Thirty years later, the military included a psychological component, stating the soldiers must be of sound mind (22). Due to high military involvement during the Civil War, the fitness standards were lowered in order to allow for larger numbers in the service. However surprisingly, during this time point height-weight tables were first produced. Because height and weight were thought to have a direct linkage to health, strength, and military bearing, tables were created. Therefore, in 1887 the first official tables were enforced throughout the United States Army (13,22).

A height-weight table provided minimum, and later maximum, weight for height values. It was thought if an individual failed to meet a minimum weight requirement, then they were most likely prone to have stamina deficiency, lower resistance to fatigue, and potentially pulmonary tuberculosis. It was not until 1960 that maximum weight values were implemented (13). If an individual did not fall between the minimum and maximum values, they were evaluated by a medical advisory board. The advisory board then utilized an equation, which assessed chest circumference as well as height and weight. In addition, the men's bodies were subjectively analyzed to determine ability of strength and competency (22). In 1918, the government determined the standards for physical fitness were too subjective. As the standards fluctuated between states and boards, as well as by month, there was no set protocol to follow. The military concluded a large number of soldiers were potentially falsely admitted while a number were excluded and should not have been (22).

In 1940, the dependability of the height-weight tables was contemplated due to the exclusion of age and race. Gender was not included at this point in time as women were not yet able to join the ranks prior to 1940. Researcher, Adolphe Quetelet determined that weight increases with age; this posed problematic as individuals would have been dismissed from the military despite still performing the job to the same ability as the previous weight screenings years prior (22).

Alterations to the height-weight tables were released in the Army Regulation report (AR) 400-503 in May 1956. Further changes to the report were released later in 1956 and again in 1959 (31). These modifications encompassed a ±15% allowable weight standard determined by a physician. This modification allowed a physician to determine if an individual was over-fat or merely had a high level of muscularity (31). However, this returned the military to the previous subjective analyses which were used approximately a hundred years prior. Therefore, in 1959 the criteria were more objectively determined in order to eliminate bias (22).

The next major amendment made to the Army's weight standards was proposed in 1976 through AR 600-9. The report suggested the implementation of the Army Physical Fitness and Weight Control Program. Previous to the AR 600-9, the height-weight tables were not constructed on physiologically thorough philosophies. The report proposed the use of Body Mass Index (BMI) values. As BMI requires only quick height and weight measurements, it eliminated researcher error and allowed anyone within a unit to perform fitness evaluations. AR 600-9's plan went into effect in July 1977, eliminating subjective physician bias (22). However, the use of BMI did not last long due to unequal standards between males and females as a male could potentially achieve a lower body fat percentage more easily than a woman with the same BMI (22).

In 1983, a revised AR 600-9 report was released utilizing skinfolds in order to determine percentage body fat if the individual failed the height-weight tables. Skinfolds were taken using a four site method including bicep brachii, tricep brachii, subscapular, and suprailiac. If an individual failed the initial screening, they were sent to the Medical Department Activity (MEDDAC) for a trained officer, who was generally either a dietitian or physical therapist, to perform skinfolds (31).

Small cohorts of individuals were chosen to be skinfold testers. Once picked, the individuals were trained for reproducibility. Interestingly, these groups were trained utilizing another individual as their "gold standard" who had previously been calibrated with hydrostatic weighing. Once the group was trained, they would train others to perform skinfolds. However, it did not take long for the military to realize discrepancies in skinfold testing. Additionally, skinfolds added a tremendous amount of work for the MEDDAC staff (31). Consequentially, the military decided a new method needed to be put in place. The U.S. Army tasked the Exercise Physiology division of Research of Environmental Medicine with determining a new method which would produce more accurate values of percentage body fat while eliminating complicated testing procedures. Additionally, their requirements included finding a test which would have less variability between measurers (31).

A set of guidelines were set forth to determine a new method for testing. Those guidelines were to: "a) contain no skinfold measurements b) emphasizes circumference measures at easily locatable anatomic sites c) not to exceed 4 measurements, excluding height and weight d) be able to be executed by non-technically trained personnel e) does not require elaborate or unavailable equipment f) common equation for all race/ethnic groups g) avoid measurements that require undressing beyond the Army sport ensemble h) selected equations must have a correlation coefficient of at least 0.80 with hydrostatically determined percentage body fat, and a standard error of the estimate not greater than 4.0% body fat. i) equations should give comparable results in the three major race/ethnic groups" (31).

Utilizing the given parameters, a study was performed using 1,194 males and 319 females as participants. The study compared hydrostatic weighing to 9 diameter and 14 circumference measurements. The diameter measurements included: biacromial, chest, biiliac, deltoid, bitrochanter, elbow, wrist, knee, and ankle. While the circumference measurements consisted of: head, neck, bicep-relaxed, bicep-flexed, shoulder, chest, abdominal-1, abdominal-2, hip, forearm, wrist, thigh, calf, and ankle. Additionally, height and weight were taken. From this data, approximately 35 equations were created and compared to the previously provided parameters. Ultimately two equations, a male and female, were chosen optimal for Army standards. The male equation created, which utilized imperial units of inches and pounds, was %Body Fat = 46.892 – (68.678 x Log_{10} height) + (76.462 x Log_{10} (abdominal-2 circumference – neck circumference)) (31). This equation has now been changed multiple times since first published.

The military was not satisfied that the most accurate fitness standards and body fat percentage testing were being upheld. Therefore, various techniques such as film radiographs, skinfolds, electrical impedance, and circumference taping were evaluated. However, due to practicality and ease of testing, taping was adopted as the main determinant of body fat percentages. This technique is still utilized in the U.S. Army today, although not without skepticism (22).

Current Policies and Goals

Military personnel undergo physical fitness testing semiannually. Testing involves a 2 mile run, push-ups, sit-ups, and body composition screening via height-weight tables (13). If an individual fails to keep their weight under the maximum allowance for their height, then they undergo circumference measurements. This allows over muscular individuals to be separated from over-fat individuals. Taping measurements utilize the aforementioned equation to determine an estimated body fat percentage value. The value is then compared to the allowable percentage body fat for their age and gender group. If an individual fails to remain under the maximum allowable percentage body fat, they are enrolled in the Army Weight Control Program. Once enrolled, the individual’s commander will present them with nutrition education sessions and an exercise program. In addition to providing motivational curriculum, military personnel are also incentivized through the use of negative punishment. This can occur in the form of a flag on their record which can impede reenlistment, awards, transfers, and promotions (13).

Once placed in the Army Weight Control Program and provided with the necessary tools to succeed, a soldier is allowed two months to show progress in their body composition. This is signified by a weight loss of 3 to 8 pounds weight loss per month for two consecutive months. If the soldier does not show improvement they may be discharged from the military (13).

Methods of Body Composition Testing

Body composition (body fat percentages) can be measured using skinfold thickness, bioelectrical impedance, hydrostatic weighing, and dual-energy X-ray absorptiometry. However, all of these procedures of testing have both advantages and disadvantages.

Skinfold measurements, a reliable and valid technique, are rooted in the notion there is an association between subcutaneous body fat and total body fat percentages. Skinfold measurements utilize standardized anatomic locations which are then inputted into an equation to estimate body density. Once known, fat-free mass and percentage body fat can be calculated (1). The advantages of this method are the ease of access, quickness, low cost, simple field administration, and little participant involvement (6). Additionally, skinfolds are advantageous because they are resistant to quick changes in hydration levels unlike alternative techniques (1). However, skinfold measurements require a trained technician and are known to have large amounts of variability in results between testers (6). Skinfold measurements also require appropriate prediction equations based upon specific populations. Additionally, it also does not measure visceral fat and only samples a small number of skinfold sites.

Bioelectrical impedance (BIA) is another technique for determining body fat percentages. BIA relies on electrical currents that flow through the body at varying resistance depending on fat mass to fat-free mass ratios. BIA can determine one's total body water, fat-free mass, or body fat percentages through either single or multi-frequency analyses (1). Similar to skinfolds, BIA are advantageous due to ease of access, quickness, low cost, simple field administration, and little participant involvement. However, a major disadvantage of BIA is its variability due to hydration status. When dehydrated, there is an underestimation of fat-free mass therefore causing an appearance of higher percentage of body fat (21).

Hydrostatic weighing, also called underwater weighing (UWW), is currently considered the "gold standard" of body density and fat-free mass testing. UWW estimates total body volume through Archimedes' principle which states that the water displaced by the body's volume is directly related to the difference of the body weight minus the weight of the body while in the water. Body density can then be calculated and lastly percentage body fat can be determined (21).

UWW can be a disadvantageous method of testing body fat for numerous reasons. First of all, UWW requires great subject involvement, as the test requires individuals to exhale all of their air before submerged, which may uncomfortable. Additionally, participants must remain as still as possible while under water, making it impractical for children, elderly, or hydrophobic individuals. In the same notion, individuals who are of large body composition may not be able to fit into the basket or fully submerge their heads under water for testing. UWW also must take into account ones residual lung volume and volume of gas in the gastrointestinal tract, and therefore, could be a large source of error if not determined accurately (21). Lastly, UWW does not account for bone mineral density. Due to its use as the "gold standard", the circumference equations put forth by each branch of the military were created based on underwater weighing (16).

The newest, and most up-and-coming, method for body composition testing is dual-energy X-ray absorptiometry (DXA). DXA is a valid method for determining body fat percentages and has been found to have a reproducibility of 0.5% body fat. Dual-energy X-ray absorptiometry utilizes a direct approach of X-ray beams with high and low photon energies to determine an individual's lean soft tissue, visceral adipose tissue, fat, and bone mineral density can be gathered. Furthermore, these measurements can be gained through a quick, painless scan which does not require any subject involvement (21).

The DXA also requires less researcher training when compared to techniques for estimating body composition such as hydrostatic weighing and skinfold thickness measurements, reducing the risk of human error (2). Additionally, DXA eradicates the variability in results due to residual lung and gastrointestinal volumes (16). Another benefit of DXA scans are its resistance to acute hydration fluctuations. DXA scans are an optimal method for reliable testing on most demographics of people including children and geriatric populations. However, due to small amounts of radiation exposure, DXA is not permitted for pregnant individuals (21). Additionally, while DXA is a constructive method for testing, it is expensive and not practical in military settings. Lastly, DXA manufacturers have different proprietary formulas which result in different estimations of body compositions.

Previous Military Research

While there have been numerous studies investigating various body composition techniques, there has been minimal research investigating the Army's taping method. However, studies which investigated military's circumference measurements have utilized tools such as bioelectrical impedance, skinfold thicknesses, and dual-energy x-ray absorptiometry. Additionally, each branch of the military uses different circumference measurement equations based on level on stringency for body fat percentage allowances.

Babcock et al. (6) compared the Army, Marine Corps, Navy, and Air Force's circumference measurements to skinfold thicknesses in 1,191 male firefighters with a mean age of 37.9 ± 7.9 years. The circumference measurements were taken at three sites: the neck, abdomen, and hips; while skinfold measurements were recorded at the chest, abdomen and thigh sites. The authors analyzed the data using the Jackson and Pollock (6) skinfold equation to determine body fat percentages.

The results depict a trend towards overestimation of body fat percentages when analyzing circumference equations compared to skinfolds with the overestimation trend being more pronounced in larger individuals ($p < 0.005$). Therefore, by using the circumference equations more individuals were designated as noncompliant with military fitness requirements compared to skinfold equations (6). The authors suggested using caution when evaluating soldiers with the taping method due to potential misclassifications of being over-fat (6).

Other studies sought to determine alternative techniques than circumference taping such as BIA and skinfold to determine body fat percentage predictions. However the validity and reliability of such techniques are under much speculation. Aandstad et al. (1) sought to compare the validity and reliability of BIA and skinfolds, as well as a combination of the two through utilizing multiple regression equations, to DXA. Their results suggested that there was not a specific skinfold equation for men which appeared to be optimal for both reliability and validity. However, the Jackson and Pollock equation resulted in the smallest test-retest values. It also demonstrated a great underestimation of body fat percentage when compared with the estimations using DXA. Furthermore, the prediction equations combining skinfold and BIA produced the most reliable results. The authors concluded neither skinfold, BIA-skinfold combination, or BIA alone can be deemed better than alternative methods (1).

Despite BIA's large variability in results due to an individual's fluid balance, it can be beneficial in field settings, such as military bases or camps (2,23). Kremer et al. (23) investigated the validity of the Air Force's circumference equations with BIA and underwater weighing to determine body fat percentages in 100 active duty males (n = 50) and females (n = 50). The results determined BIA might not be a superior method of testing compared to the Air Force's taping method. The Air Force's circumference measurements classified males as noncompliant with weight standards by 5.9% more than testing percentage body fat with BIA. A "false positive" can be detrimental to an individual as it inaccurately classifies them as overweight. Additionally, taping in the males produced significant ($p \leq 0.05$) overestimations of percent body fat by 1.3%. In men, the sensitivity of taping (probability of the number of true positives) compared to underwater weighing was 81.3%, while BIA was 68.8%. The specificity of taping (probability of the number of true negatives) was 85.3% while BIA was 91.2% in men (23). This signified BIA rated less individuals as non-compliant, but in a similar notion, it also classified over-fat individuals as normal weight. Thus, individuals who should be placed in the AWCP are not being challenged to lose adipose tissue. The results demonstrated both BIA and taping methods should be used with caution in the military setting (23).

Similarly, Shake et al. (29) compared circumference measurements and underwater weighing in 49 Navy males who were estimated by their commanders to have ≥22% body fat. For this study, individuals were specifically chosen based on being classified as over-fat by the circumference equation standards. The men's circumference measurements were taken at the neck and abdomen sites while using the Navy's circumference equation. The results revealed the circumference equations yielded a 6.8-18% false positive rate. Individuals who are over 22% body fat are being labeled as non-compliant with military body composition standards. The authors suggested using caution with circumference measurements and that one's values should be taken into consideration with overall job performance before they are falsely reprimanded (29).

Karl Friedl and James Vogel (16) examined the validity of circumference equations to DXA. For this study 496 male soldiers were evaluated. The men underwent a DXA scan and circumference measurements which were taken at the level of the neck and abdomen. The values were then analyzed using the Marine Corps, Navy, and Army equations. However, it should be noted the Army equation used in this study is now outdated as of 2002 (16).

Friedl and Vogel (16) concluded for all equations men with higher body fat percentages were underestimated in their percentage body fat. The three branches of the military yielded extremely comparable percentage body fat values with each other. However, the Army's equation produced the most comparable values to the DXA opposed to the Marine Corps and Navy equations. Friedl and Vogel (16) concluded circumference equations may be an appropriate estimation of body fat percentages because they account for abdominal girth which is a primary focus for good physical appearance. The authors argued due to the specificity of abdominal girth, the equations are perhaps beneficial (16).

While there is data supporting the rationale for the Army's height-weight tables and circumference assessments, little research has examined the agreement between the circumference equations and dual-energy x-ray absorptiometry. Friedl and Vogel (16) examined the validity, rather than agreement, of percentage body fat predicted from circumference measurements when compared to dual-energy X-ray absorptiometry. Since then a new circumference equation was proposed, therefore replacing the 1997 equation. As of 2002, this new equation is still currently being used by the Army (17). To date, agreement between DXA and the new equation (17) has yet to be examined. Additionally, while DXA can be valuable for determining overall body fat percentages, it is expensive and not practical in military settings. Therefore, it is of utmost importance to determine the benefits of circumference equations due to their low cost and ease of access.

However, it has been proposed that use of the height-weight tables and circumference measurements are problematic. Due to the negative stigma of needing to be taped, the height-weight tables may cause or reinforce disordered eating and exercising in some soldiers (10). Furthermore, because promotions and job security are contingent upon passing fitness testing semiannually, there is an excessive amount of pressure placed on the soldier to maintain a healthy weight (10,30). Additionally, as the military is downsizing and eliminating excess cost, there is further increased tension on soldiers to maintain positive military bearing (30). Inflated body fat percentages determined by circumference measurements places the soldiers at an elevated risk for anxiety and may ultimately result in military discharge (6,23,29). In conclusion, due to the disagreement in taping reliability, there is a need for further research.

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CHAPTER II

AGREEMENT IN THE ARMY'S CIRCUMFERENCE MEASUREMENTS AND DUAL-ENERGY X-RAY ABSORPTIOMETRY

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Abstract

The United States military has two primary outcomes for fitness: combat readiness and physical appearance. In response to the Army Weight Control Program, height-weight tables and circumference measurements were established to evaluate soldiers' body fat percentages and screen for overweight individuals. However, few studies have examined the agreement in body composition estimates between the Army's circumference measurements and dual-energy x-ray absorptiometry (DXA). The purpose of this study was to quantify the agreement in body fat percentage estimates between the Army's circumference measurements and dual-energy x-ray absorptiometry in male Army Reserve Officers' Training Corps (R.O.T.C.) cadets. Male, R.O.T.C. cadets ($N = 23$) between the ages of 18-24 from Central Washington University's R.O.T.C. program were used as participants. Participants underwent taping according to Army protocol, and a DXA test to examine percentage body fat. Utilizing SPSS, a Bland-Altman Plot was used to analyze the quality of agreement for continuous variables. There was a significant negative correlation between the difference (taping – DXA) in percentage body fat and the DXA scores ($r = -0.722$, $p < 0.001$), indicating poor agreement between the taping field test and DXA laboratory criterion. The results depict little methodological agreement in percentage body fat between taping and the DXA. When analyzing the categorical variables, overweight and over-fat, there is a moderate level of agreement between the height-weight tables and DXA methods as demonstrated by the 78.3% percent of agreement. This study has brought awareness to the underestimation of percentage body fat when using the taping method. Therefore, cadre can better tailor training regimen.

Key Words: DXA, taping, military, body composition

INTRODUCTION

The United States military has two primary outcomes for fitness: combat readiness and physical appearance. When the Army Weight Control Program (AWCP) was created in the early 1980s, its fundamental principle encompassed military bearing (appearance) with health concerns being secondary outcomes (19). In response to the AWCP, height-weight tables were put forth to evaluate soldiers' body compositions and screen for overweight individuals (19). Height-weight tables compare height and age values to provide a maximum weight requirement (11). Those exceeding the allowed body weight are then circumference measured, colloquially known as "taped", to determine body fat percentage (5). Circumference measuring is thought to be beneficial as it differentiates those who are overweight due to high muscle mass. In compliance with the AWCP, if an individual is over-fat they are placed in a weight control program to improve physical appearance (17). Male individuals between 17-20 years are allowed 20% body fat while those between the ages of 21-27 are allowed 22% (11).

As military bearing is imperative for career advancement, it is crucial to examine the methods with which physical appearance is being tested (6, 10, 18). Consequentially, previous studies have examined the validity of the military's circumference equations using techniques such as skinfolds, bioelectrical impedance (BIA), underwater weighing (UWW) and dual-energy X-ray absorptiometry (DXA) and found both agreement (16, 17) and disagreement (6, 23, 29).

Despite using different methods of testing, previous research has found taping can lead to misclassifying males as non-compliant with percentage body fat standards by 5.9-18% (23, 29). A “false positive” can be detrimental to an individual as it inaccurately classifies them as overweight. Studies have also found taping significantly overestimates body fat percentages ($p < 0.005$, $p < 0.05$) in all military branches with the overestimation being more pronounced in larger individuals (6, 23). Therefore, by using the circumference based equations more individuals were designated as noncompliant with military fitness equations (6,23,29).

While there is data supporting the rationale for the Army's height-weight tables and circumference assessments, no research has examined the agreement between the circumference equations and dual-energy x-ray absorptiometry. DXA is a valid method for determining body fat percentages and has been found to have a reproducibility of 0.5% body fat. DXA determines an individual’s fat mass from fat free mass using direct approach of x-ray beams, which pass through the body. Additionally, the DXA requires less researcher training when compared to techniques for estimating body composition such as hydrostatic weighing and skinfold thickness measurements, therefore reducing the risk of human error (2).

Friedl and Vogel (16) examined the validity of percentage body fat predicted from circumference measurements when compared to dual-energy X-ray absorptiometry and concluded that circumference equations may be an appropriate estimation of body fat percentages because they account for abdominal girth which is a primary focus for good physical appearance. The authors argued due to the specificity of abdominal girth, the equations are perhaps useful for assessing good physical appearance (16). In 2002, a new circumference equation was proposed, which is still currently being used by the Army (17). To date, agreement between DXA and the new equation (17) has yet to be examined. Additionally, while DXA can be valuable for determining overall body fat percentages, it is expensive and not practical in military settings. Therefore, it is of utmost importance to determine the benefits of circumference equations due to their low cost and ease of access.

However, it has been proposed that use of the height-weight tables and circumference measurements are problematic. Due to the negative stigma of needing to be taped, the height-weight tables may cause or reinforce disordered eating and exercising in some soldiers (10). Furthermore, because promotions and job security are contingent upon passing fitness testing semiannually, there is an excessive amount of pressure placed on the soldier to maintain a healthy weight (10,30). Additionally, as the military is downsizing and eliminating excess cost, there is further increased tension on soldiers to maintain positive military bearing (30). Inflated body fat percentages determined by circumference measurements places the soldiers at an elevated risk for anxiety and may ultimately result in military discharge (6,23,29).

Therefore, the purpose of this study was to quantify the agreement in body fat percentage estimates between the Army's circumference equations and dual-energy x-ray absorptiometry in male Army Reserve Officers' Training Corps (R.O.T.C.) cadets.

METHODS

Experimental Approach to the Problem

This study was an experimental descriptive study. The main aim was to provide values comparing percentage body fat values from circumference measurements and dual-energy X-ray absorptiometry. The primary outcome variable was percentage body fat, which was selected in accordance with Army taping protocol outcomes.

Subjects

Approval was granted by the university's Institutional Review Board and informed consent was gained from participants. Twenty-three male R.O.T.C. cadets from Central Washington University's R.O.T.C. program were used as participants. The men had an average age of 20.61 ± 1.62 years and a body mass index (BMI) of 25.35 ± 2.50 kg/m^2. The subjects' body mass index (BMI) values placed them in the normal to obesity class I range (3).

Procedures

Taping was performed on all individuals, regardless of whether they passed the height-weight tables in order to allow for a larger number of participants. Participants were excluded if taking glucocorticoids or thyroid medications. Current smokers or individuals actively dieting or who had lost ten pounds or more in the previous three months, signifying an unstable body composition were also excluded. Additionally, the participants must have abstained from alcohol for 24 hours prior to testing.

The following procedures were performed: height, weight, circumference measurements, and a dual-energy X-ray absorptiometry test. The testing for each participant consisted of one day during which the participants were at Kittitas Valley Healthcare Hospital for no more than twenty minutes.

The participants' height and weight were taken by the radiology technician. Height and weight measurements were taken in standard metric units (kilograms/centimeters) and were converted to imperial units (pounds/inches) in accordance with the Army's protocol listed in the field manual (FM) 600-9 (11). Once the participants' shoes were removed the height was taken in the cadets' Army Improved Physical Fitness Uniform (IPFU), which consists of IPFU issued ankle high cotton socks, trunks, and short sleeve shirt. The participants were asked to maintain a straight but not rigid body as well as to keep their head held horizontal with their chin parallel to the floor while looking straight forward. In standard metric units, the height was taken in centimeters to the tenths place. Participants' weight was conducted in the same clothing protocol as the height and was taken in kilograms to the hundredths place and converted to imperial units (11).

Anthropometric Circumference Measurements

Anthropometric circumference measurements were taken three times sequentially at both the neck and abdominal sites using a fiberglass tape measure. The participants were asked to wear only shorts for circumference testing as compression shorts are too constricting for abdominal measurements and can potentially lead to skewed results. Values were recorded to the nearest half inch. The three measurements were averaged as long as the values were within one inch of each other. If the measurements were not within an inch then a fourth measurement was taken and the closest three measurements were averaged. Neck measurements were taken at the mark just below the larynx and perpendicular to the neck's long axis. Cadets were instructed to have relaxed shoulder posture while looking straight forward. In accordance with Army protocol (11), measurements were recorded up to the nearest half inch (16 1/4 inches becomes 16 1/2 inches). Abdominal measurements were taken at the naval and parallel to the floor while the participant maintained arms directly by their side. The measurements were recorded at the end of their normal relaxed exhalation. Measurements were recorded down to the nearest half inch (34 3/4 inches becomes 34 1/2 inches). Values taken from circumference measurements and height were then be used to calculate an estimated body fat percentage using the equation: % body fat men = [86.01*LOG_{10} (waist- neck)]-[70.041*LOG_{10} (height)] +36.76 (11). In accordance with Army protocol, those participants between the ages of 18-20 years must be below 20% body fat while those between the ages of 21-24 must maintain equal to or less than 22% body fat (11).

Dual-Energy X-ray Absorptiometry

Dual-energy X-ray absorptiometry was used to assess whole body soft tissue composition, specifically, body fat using a GE Lunar Prodigy Advance with 13.3 Lunar Software (GE Healthcare, Madison, WI). The participant was asked to lie on the scanning table while completely motionless throughout the duration of testing, which consisted of several one minute scans. Participants were allowed to wear their IPFU for testing since there were no buttons, metal, or zippers. All DXA testing was performed by a DXA specialist who has been trained in radiology and calibrated the device daily.

Statistical Analyses

A Bland-Altman (BA) plot was used to assess the methodological agreement between a field measure (the Army's circumference equations) and a laboratory criterion (DXA) for body fat percentages. The original Bland-Altman plot (9) was modified in two important ways. The difference in body fat percentages (circumference equations – DXA) was plotted on the y-axis against the DXA-derived values for body fat percentages on the x-axis. Because DXA is a three-component criterion estimate of body fat, it is a more direct and less biased estimate of "true" body fat than the average of the body fat estimates from the circumference equations and DXA. In the original Bland-Altman plot, the average of the estimates from the two methods is plotted on the x-axis. Second, because the difference in percentage body fat values were significantly and inversely correlated with the DXA percentage body fat values, the methodological agreement as the statistically significant regression line ± 2 standard errors of the estimate (SEE) were graphed (35). In the original Bland-Altman plot, the relative accuracy or bias in methodological agreement was graphed as the mean difference ± 2 standard deviations. Because there was a significant inverse correlation between the difference scores and the DXA scores, the poor methodological agreement is better displayed as the regression line ± 2 SEE because it more clearly shows that the underestimation of body fat by the circumference equations becomes more severe in those individuals with higher DXA-derived criterion estimates of body fat percentage.

A paired t-test was employed to determine the average bias in body fat percentage estimates between the circumference equations and DXA.

Although it was intended to assess the agreement between the circumference equations and DXA for classifying cadets into not over-fat and over-fat categories, there were no cadets in our sample who were classified as over-fat by the circumference equations. Thus, the agreement between the Army's height and weight table (which assesses the presence or absence of overweight) and DXA (which assesses the presence or absence of over-fat) was assessed. A 2 x 2 contingency table was used to assess the categorical methodological agreement between overweight and over-fat with a chi-square test, a kappa coefficient of agreement, as well as estimates of the percentage of agreement, the sensitivity, and the specificity. The percentage of agreement was defined as the sum of true positives and true negatives. True positives were defined as the percentage of the total sample classified as both overweight and over-fat. True negatives were defined as the percentage of the total sample classified as neither overweight nor over-fat. Sensitivity was defined as all of those classified as over-fat by DXA who were also classified as overweight by the Army's height-weight table (probability of the number of true positives). Specificity was defined as all of those classified as not over-fat by DXA who were also not overweight by the Army's height-weight table (probability of true negatives). For all statistical analyses, alpha was set at $p < 0.05$ as significant.

RESULTS

Participant Characteristics

Twenty-three healthy male R.O.T.C. cadets, as described in Table 1 (*Mean* ± SD & range), participated in this study. As seen in Table 1, the mean percentage body fat was significantly lower when analyzed with taping than with DXA ($p < 0.001$). Based on questionnaire data, the men self-reported to consume an average of 2,364.45 ± 1,479.78 mL water daily.

Table 1. Descriptive characteristics for participants.

Characteristic	Mean ± SD	Range
Age (yrs.)	20.61 ± 1.62	18-24
Height (cm)	179.06 ± 6.60	166.50-195.00
Weight (kg)	81.43 ± 10.34	61.10-104.40
BMI (kg/m^2)	25.35 ± 2.50	21.27-30.34
Percentage Body Fat (%)-DXA	17.24 ± 6.00*	3.20-21.20
Percentage Body Fat (%)-Taping	13.49 ± 4.17*	7.40-26.30

*Denotes significant difference ($p < 0.001$).

Taping Analysis

As previously mentioned, cadets were taped regardless of whether they passed the height-weight tables. Of the 23 participants tested, 8 cadets failed because they were classified as overweight (34.8% of the total), therefore signaling the need for taping. When analyzing body composition using the taping method, none of the cadets were classified as noncompliant due to an unsatisfactory body fat percentage (over-fat). However, using the DXA method, 7 cadets were classified as over-fat because they had a higher than permitted body fat percentage (30.4%).

Taping - DXA Agreement

There was a significant negative correlation between the difference scores (taping – DXA) and the DXA percentage body fat ($r = -0.722$, $p < 0.001$), indicating poor agreement between the taping field test and the DXA laboratory criterion (Figure 1). This indicates that the bias toward lower body fat percentages with taping becomes more pronounced in those with higher DXA-derived body fat percentages. Figure 1 also shows that 20 of 23 cadets (86.9%) had a lower body fat percentage from taping than from DXA (e.g., a negative difference score).

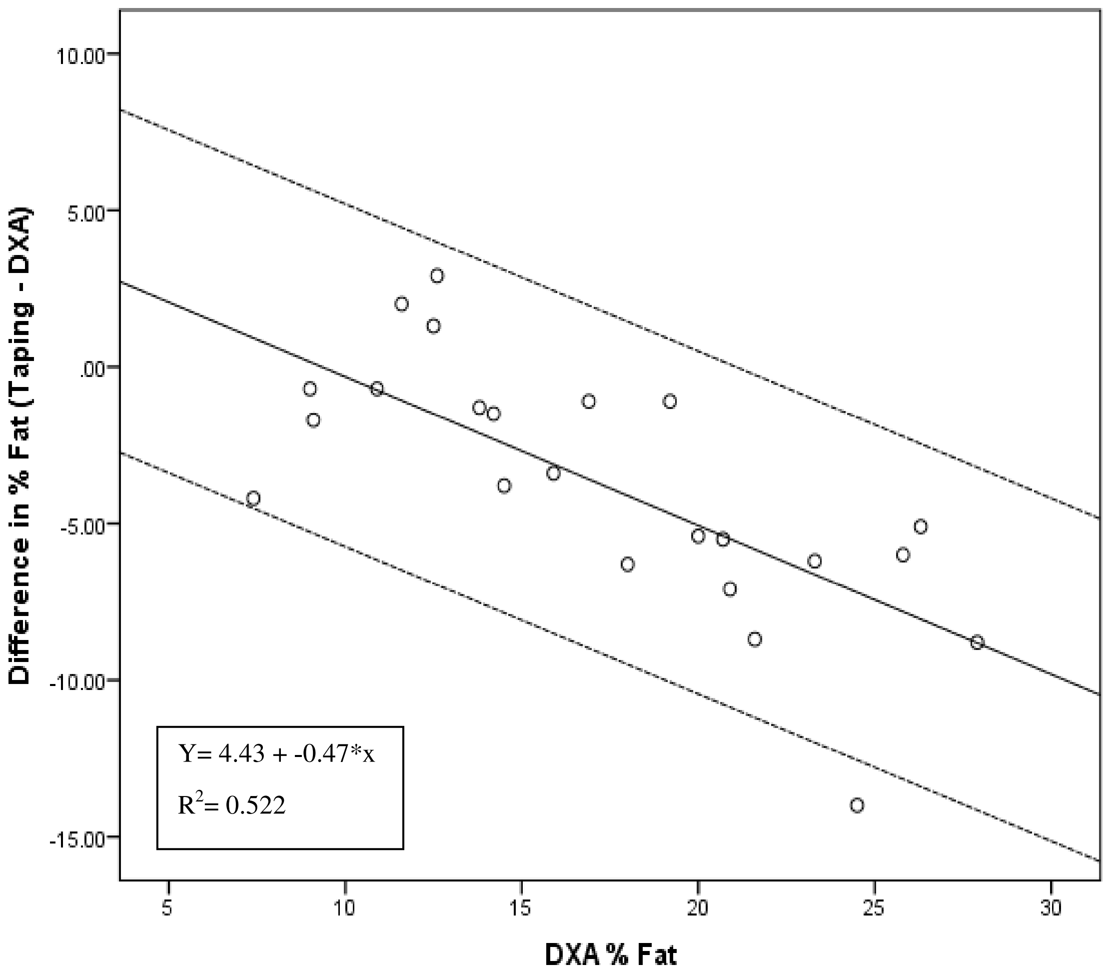

Figure 1. Comparison of predicted body fat percentage between dual energy X-ray absorptiometry and taping methods. Because the slope of the regression is significant ($p < 0.001$) the solid line is the regression line, and the dotted lines are the regression lines ±2 standard error of estimate (35).

Categorical Agreement between Height-Weight Table and DXA

Table 2 displays the results from the 2 x 2 contingency table. The percentage of agreement was 78.3% while the sensitivity was 71.4% and specificity 81.3%. The chi-square test produced a significant difference between circumference and DXA methods ($p = 0.015$). The Kappa coefficient of agreement yielded a value of 0.506 ($p = 0.015$) therefore signifying a moderate level of agreement between over-fat by the DXA and overweight by the height-weight tables.

Table 2. Height-weight tables analysis of overweight and over-fat by dual energy X-ray absorptiometry (DXA) agreement using critical body fat percentages to determine over-fat.

		Over-fat by DXA		
		Yes	**No**	**Total**
Overweight (Yes vs. no)	**Yes**	5	3	8
	No	2	13	15
	Total	7	16	23

DISCUSSION

The main findings from this study indicate that there is poor agreement between the Army's taping method and DXA. As an individual's body fat percentage increased using the taping method, there was a significant trend towards a larger underestimation of body fat percentage as reflected by the DXA. Despite poor agreement between taping and DXA, there was a moderate level of agreement between the height-weight tables and DXA. Furthermore, none of the participants were categorized as over-fat according to the taping method whereas 7 of 23 were over-fat as categorized by DXA (30% of sampled population).

Taping Analysis

The results found that none of the cadets were classified as noncompliant due to an unsatisfactory body fat percentage (over-fat) according to the taping method. This is most likely because R.O.T.C. cadets are part of a special population. Active duty Army soldiers are body composition tested semi-annually (11), while R.O.T.C. cadets are tested semi-quarterly, making the cadets more frequently tested than the average soldier. Additionally, cadets are required to engage in organized physical fitness including running and strength training up to five times per week, which could eliminate the number of unfit individuals.

Taping - DXA Agreement

The results depict little methodological agreement in percentage body fat between the Army's taping method and the DXA. When analyzing the categorical variables, there is a moderate level of agreement between the height-weight tables and DXA methods as demonstrated by the adequate percentage of agreement. For instance, 71.4% of cadets who were overweight according to the height-weight tables were considered to be over-fat when compared to the DXA and allowable Army percentage body fat limits. Additionally, 81.3% of cadets who passed the height-weight tables, signifying no need for taping, were also not considered over-fat by the DXA.

The results of the modified BA plot demonstrate that as a cadet's percentage body fat increases, there is a trend towards underestimation in percentage body fat estimated through taping. This is contradictory to previous research where others have found an overestimation of percentage body fat when using the taping method (6,23,29). However, the current findings are not entirely surprising as the Army gives a soldier the benefit of the doubt through rounding in the taping technique. The neck measurements are rounded up to the nearest half or whole number, while the abdomen measurements are rounded down to the nearest half or whole number (11,16). This allows soldiers to appear to be bigger in the neck while smaller in the waist thus providing the soldier with a more favorable percentage body fat value.

Allowing taping to underestimate percentage body fat may be both beneficial and detrimental for the Army. Because taping might not classify a soldier as non-compliant, there is a higher level of job security and less potential for black marks on their record or potential dismissal (6,13,29). However, because individuals are given lower estimations of percentage body fat; there is a possibility that soldiers are not being reprimanded for excess weight. Additionally, by providing lower body fat estimates individuals with excess body fat are potentially not being placed in the AWCP. Therefore, they are not provided with nutritional and exercise programs to maintain positive military bearing.

The current findings contradict previous research (6,23,29). Babcock et al. (6) concluded an overestimation in percentage body fat through using circumference equations with the overestimation being more pronounced in larger individuals (6). Babcock et al.'s findings directly oppose the current study, which concluded there was an underestimation of percentage body fat, specifically more pronounced in larger individuals.

Similarly, Kremer et al. (23) found the Air Force's circumference equations yielded significantly higher percentage body fat than hydrostatic weighing ($p \leq 0.05$) (23). In addition, Kremer et al. found a 14.7% false positive rate while the current study had 0% false positive rate as none of the cadets were over the allowable percentage body fat when estimated with taping. Shake et al. (29) also found circumference equations yielded 6.8-18% false positive rates in those with ≥ 22% body fat, therefore signaling an overestimation of body fat through the taping method (29). However, a benefit of the current study is the low false positive rate. Therefore, individuals are not unduly being punished.

Interestingly, the current findings are in alignment with Friedl and Vogel's (16) findings in 1997, which also analyzed body composition compared to the DXA. Despite using a now outdated equation, Friedl and Vogel (16) also found circumference equations underestimate body fat, specifically around 20% body fat. Regardless, Friedl and Vogel suggest due to the ease of the equations and specific targeting of abdominal fat, taping is a sensible method (16).

Categorical Agreement between Height-Weight Table and DXA

The categorical agreement results in the current study demonstrate that the height-weight tables are a positive tool for determining if an individual will be considered over-fat. Therefore, the height-weight tables perhaps may be considered a beneficial screening tool at this point in time. To the best of the authors' knowledge, no other studies have examined the height-weight tables in comparison to a DXA. Additionally, there is little published data regarding the height-weight tables except for those examining its impact on eating disorders (4,8,25,30,33)

The current study is not without limitations. First, there was a small sample size (N = 23). A small sample size could potentially not allow for a wide range of body compositions to be evaluated.

Taping should be used with caution because of the tendency to demonstrate an underestimation of percentage body fat, specifically in larger individuals. Furthermore, by not placing individuals in the AWCP there might be a trend in the coming years of a less favorable appearance of those in the military. Therefore, future research is needed to determine whether the taping method is an accurate method of body composition testing. Research should examine the Army's taping method with a larger sample size of R.O.T.C. cadets. Additionally, future research should analyze the agreement between taping and the DXA over a wider age range. Lastly, future studies should examine active duty soldiers rather than R.O.T.C. cadets.

PRACTICAL APPLICATIONS

This study has brought awareness to the underestimation of percentage body fat when using the taping method. Through the results of this study, cadre can better shape the training regimen of cadets. By understanding individuals are being underestimated, the cadre should train those needing taped more rigorously.

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Appendix A

Army's Height-Weight Table

Table B-1 Weight for height table (screening table weight)

		Male weight in pounds, by age			
Height (inches)	Minimum weight[1] (pounds)	17-20	21-27	28-39	40+
58	91	-	-	-	-
59	94	-	-	-	-
60	97	132	136	139	141
61	100	136	140	144	146
62	104	141	144	148	150
63	107	145	149	153	155
64	110	150	154	158	160
65	114	155	159	163	165
66	117	160	163	168	170
67	121	165	169	174	176
68	125	170	174	179	181
69	128	175	179	184	186
70	132	180	185	189	192
71	136	185	189	194	197
72	140	190	195	200	203
73	144	195	200	205	208
74	148	201	206	211	214
75	152	206	212	217	220
76	156	212	217	223	226
77	160	218	223	229	232
78	164	223	229	235	238
79	168	229	235	241	244
80	173	234	240	247	250

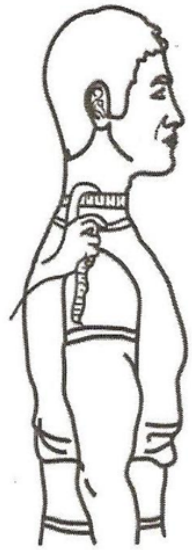
Notes:

[1] Male Soldiers who fall below the minimum weights shown in table B-1 will be referred by the commander for immediate medical evaluation.

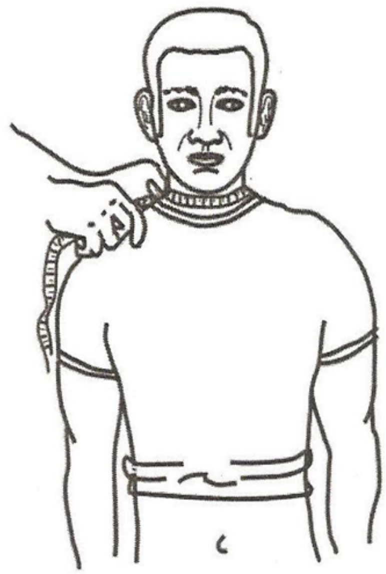
[2] Add 6 pounds per inch for males over 80 inches and 5 pounds per inch for females over 80 inches.

Appendix B

Army's Taping Anthropometric Locations



NECK - Men



NECK - Men

WAIST - Men