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## Body Composition of Reserve Officers Training Corps (ROTC) Cadets: A Comparison Across Three Techniques of Measurement

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Body Composition of Reserve Officers Training Corps (ROTC) Cadets:  
A Comparison Across Three Techniques of Measurement

Namrata J. Dave

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**Table of Contents**

Abstract.....3

Introduction.....4

Purpose Statement.....6

Literature Review.....6

Methods.....19

Results.....20

References.....25

Appendices.....31

### **Abstract**

**Background:** Physical fitness is imperative for the Army Reserves Officers' Training Corps (ROTC) cadets to be commissioned for active duty. This project compared the standard anthropometric assessment of ROTC cadets using tape measurement to body composition measurements using Air Displacement Plethysmography (ADP) from the Bod Pod and the seven-site Pollock Skin Fold Thickness (SFM) measurement. These results were compared to the norms established by the Army Physical Fitness Test (APFT), recommending to improve ROTC body measurement method.

**Method:** Thirteen ROTC cadets were recruited from Central State and Cedarville Universities. Cadets were measured using the ADP (BODPOD) and SFM method. Tape measurements were provided by the ROTC program. Descriptive statistics were generated and classifications for each cadet were made based on APFT standards for the aforementioned methods. T-test and Bland-Altman tests were conducted to compare the classifications.

**Results:** Numbers indicate, the three methods measuring body composition present different body fat outcomes for each candidate. The SFM overestimated body fat and the tape measurement underestimated body fat when the ADP measurement is used as a gold standard.

**Conclusion:** Three individuals were classified as "Risky (low body fat)" by Tape Measurement but as "lean" or "moderately lean" by SFM and the "gold standard" ADP. These results indicate that the systematic underestimation by the tape measurement can cause unnecessary concern and follow up, using limited resources unnecessarily. We recommend that ROTC use ADP body fat testing whenever available to more accurately estimate body fat percentages for cadets. The second choice would be SFM.

*Keywords:* Air Displacement Plethysmography (ADP), skin fold thickness measurement, tape measurement, young adults, diet

**Body Composition of Reserve Officers Training Corps (ROTC) Cadets:  
A Comparison Across Three Techniques of Measurement**

Each decade since 2000 the Department of Health and Human Services has developed a list of National Health Promotion and Disease Prevention objectives to improve the health of all Americans. In December 2010 they launched the newest version called “Healthy People 2020” (Centers for Disease and Control [CDC], 2011). A new section introduced in Healthy People 2020 that was not in Healthy People 2010 defines *foundation health measures* that are used to monitor progress of the objectives. One such foundation measure is *general health status* that measures life expectancy and healthy life expectancy (CDC, 2011).

Obesity has been a problem in United States (U.S.). In a survey conducted in 2011-2012, 34% of U.S. adults and 16.2% of U.S. children and adolescents were obese (Ogden, Carroll & Flegall, 2014). The leading health indicator, *nutrition, physical activity and obesity* track the increase in obesity in the population due to increase in obesity related conditions like heart disease, stroke and type two diabetes (CDC, 2014). Body weight is not an accurate measure of a person’s obesity as it measures the combined weight of *all* the body tissues whereas body composition provides a breakdown of the proportions of fat and lean mass in the body (Esmat, 2012). This specificity is particularly important for individuals with high muscle mass (CDC, n.d.)

The generally acceptable range for body fat to be considered healthy in men is 10 to 22% and is 20 to 32% for women (Esmat, 2012). Any variation, higher or lower from the acceptable range, represents health risk.

The Army Reserves Officers’ Training Corps (ROTC) recruits cadets as young as 14 years of age and transforms them into competent U.S. Army recruits (United States Army, n.d.).

Overweight and obesity are major military medical concerns due to the obesity-related diseases and the decreased operational effectiveness of the soldiers. Physical fitness is of utmost importance for the cadets to be successfully retained and commissioned for active duty. Because body mass index (BMI) is a less accurate reflection of body fat for individuals with high muscle mass (CDC, n.d.) than the general population, body composition is measured to determine the health risk of the cadets.

In June 2013, U.S. Army regulation 600-9 (U.S. Department of Army, 2013) was established. It introduced The Army Body Composition Program (ABCP) to help soldiers maintain the required physical fitness without resorting to dangerous tactics such as fasting, diet pills, or diuretics (water pills) which will give instant weight loss but also negatively affect the health of the personnel. Body composition represents the health risk of the individual as it reveals the proportion of fat and lean mass in the body. Body composition within the recommended range confers less risk from obesity-related diseases than measures outside of recommended standard ranges (Esmat, 2012).

Measuring the body composition of the ROTC cadets is very important because they need to meet the height and weight requirements for their age and height to be eligible to be enlisted in the Army (United States Army, n.d.). Obesity directly affects their ability to perform in the Army Physical Fitness Test and could further impede their chances to enroll in the army. In general the tape measurement (body circumference) method for body composition estimation used by the Army measures the body composition with an accuracy of 3% to 3.6% body fat (Heyward, 2001).

### **Purpose Statement**

This project reviewed tape circumference measurements and skin fold thickness data collected using standard anthropometric assessment of ROTC cadets and compared the resulting body fat classifications to body composition measurements using Air Displacement Plethysmography (ADP) from the BOD POD. The results were considered in the context of data collection protocol used in the Army Physical Fitness Test (APFT) to generate recommendations to improve current ROTC body measurement methods.

### **Literature Review**

#### **U.S. Army Reserves Officers Training Corps (ROTC)**

The Validation of the National Defense Act (1916) resulted in the official formation of the Army Reserves Officers' Training Corps (ROTC) and streamlined a century-old practice of military training in civilian colleges that started in 1819. Now ROTC has 273 programs in colleges and universities across the country (U.S. Army Cadet Command, n.d.). The ROTC-trained and educated officers combine the character building aspect of self-disciplined civilians with tough centralized development training. This prevents the Army officers from drifting into inbred professional separatism and produces a strong, diverse quality of officer leadership (U.S. Army Cadet Command, n.d.).

#### **ROTC Training**

The ROTC cadets have to undergo various levels of training during their four years of training to reach and maintain required fitness level. There are four core components or *cornerstones* that determine the fitness of the cadet, which determines their readiness for the military training. The four components are cardio, strength and endurance, flexibility and body composition. Basic Combat Training (BCT) is a ten week program that transforms civilians into

soldiers and the cadets are required to train themselves before they enter in the BCT program (U.S. Army, *Becoming a soldier: Basic Combat Training*, n.d.). The cadets are required to participate in physical training sessions during the year to develop the required physical fitness to start BCT (U.S. Army, *Soldier Life: Components of Fitness*, n.d.).

Physical training (PT) sessions are conducted thrice per week and include three components: warm up (calisthenics), running two miles, and upper and lower body strengthening exercises. The intensity of these exercises is determined by an assessment of the cadet's physical condition at the start of ROTC training using the "1-1-1" physical fitness test. This test includes one minute of sit ups, one minute of push-ups, and a one-mile run (U.S. Army Physical Readiness Training Information, 2013). The cadet's score in this initial reception test determines the level of intensity for the physical training in the first few weeks. The goal of this training is to increase the fitness level of the cadets to pass the Army Physical Fitness Test (APFT).

The APFT consists of three fitness events and measuring the recruits' body fat percentage. It is a simple way of measuring major muscle group's endurance and agility as well as cardiorespiratory fitness. Physical fitness is measured using the three components of the PT sessions. The cadets are required to score a minimum of 60 out of 100 points on all the components (U.S. Army Regulation: 350-1, 2011). The cadets are not considered for promotions, institutional training or selection of assignments until they pass the APFT test (U.S. Army Regulation: 350-1, 2011). If the cadets fail the APFT, they are required to retake the test in no more than 179 days.



Table 1. *Gold Standard for APFT Calculations*

| Table B-1<br>Weight for height table (screening table weight) |  |                               |       |       |     |                                 |       |       |     |
|---|--|-------------------------------|-------|-------|-----|---------------------------------|-------|-------|-----|
| Height<br>(inches)  | Minimum<br>weight <sup>1</sup><br>(pounds) | Male weight in pounds, by age |       |       |     | Female weight in pounds, by age |       |       |     |
|   |  | 17-20                         | 21-27 | 28-39 | 40+ | 17-20                           | 21-27 | 28-39 | 40+ |
| 58  | 91   | -                             | -     | -     | -   | 119                             | 121   | 122   | 124 |
| 59  | 94   | -                             | -     | -     | -   | 124                             | 125   | 126   | 128 |
| 60  | 97   | 132                           | 136   | 139   | 141 | 128                             | 129   | 131   | 133 |
| 61  | 100  | 136                           | 140   | 144   | 146 | 132                             | 134   | 135   | 137 |
| 62  | 104  | 141                           | 144   | 148   | 150 | 136                             | 138   | 140   | 142 |
| 63  | 107  | 145                           | 149   | 153   | 155 | 141                             | 143   | 144   | 146 |
| 64  | 110  | 150                           | 154   | 158   | 160 | 145                             | 147   | 149   | 151 |
| 65  | 114  | 155                           | 159   | 163   | 165 | 150                             | 152   | 154   | 156 |
| 66  | 117  | 160                           | 163   | 168   | 170 | 155                             | 156   | 158   | 161 |
| 67  | 121  | 165                           | 169   | 174   | 176 | 159                             | 161   | 163   | 166 |
| 68  | 125  | 170                           | 174   | 179   | 181 | 164                             | 166   | 168   | 171 |
| 69  | 128  | 175                           | 179   | 184   | 186 | 169                             | 171   | 173   | 176 |
| 70  | 132  | 180                           | 185   | 189   | 192 | 174                             | 176   | 178   | 181 |
| 71  | 136  | 185                           | 189   | 194   | 197 | 179                             | 181   | 183   | 186 |
| 72  | 140  | 190                           | 195   | 200   | 203 | 184                             | 186   | 188   | 191 |
| 73  | 144  | 195                           | 200   | 205   | 208 | 189                             | 191   | 194   | 197 |
| 74  | 148  | 201                           | 206   | 211   | 214 | 194                             | 197   | 199   | 202 |
| 75  | 152  | 206                           | 212   | 217   | 220 | 200                             | 202   | 204   | 208 |
| 76  | 156  | 212                           | 217   | 223   | 226 | 205                             | 207   | 210   | 213 |
| 77  | 160  | 218                           | 223   | 229   | 232 | 210                             | 213   | 215   | 219 |
| 78  | 164  | 223                           | 229   | 235   | 238 | 216                             | 218   | 221   | 225 |
| 79  | 168  | 229                           | 235   | 241   | 244 | 221                             | 224   | 227   | 230 |
| 80 <sup>2</sup>   | 173  | 234                           | 240   | 247   | 250 | 227                             | 230   | 233   | 236 |

Notes:  
<sup>1</sup> Male and female Soldiers who fall below the minimum weights shown in table B-1 will be referred by the commander for immediate medical evaluation.  
<sup>2</sup> Add 6 pounds per inch for males over 80 inches and 5 pounds per inch for females over 80 inches.

Note: Table copied from U.S. Department of the Army, Army Regulation 600-9 (2013).

### ROTC Body Composition Screening

The importance of body composition assessment methods is increasing due to increased awareness about the importance of physical fitness for healthy life. Body weight tells the combined weight of body tissues (fat, bone, muscle) whereas body composition tells the proportion of fat and lean mass in the body. Body Composition consists of two main components fat mass (FM) and fat free mass (FFM). FM consists of essential and non-essential fat. A minimum amount of fat required for necessary physiological functions is called essential fat and any fat above the minimal is called non-essential fat (Esmat, 2012).

At the time of ROTC training the cadets represent a “generalized population” of young adults rather than a specific subset such as collegiate athletes. The body fat percentage in the cadets is calculated by conducting circumference measurements of the neck and the abdomen area for men and neck, abdomen and hip area for women. The values are then placed in the following regression derived predicted equations for the body fat calculation (DOD, 2002):

$$\text{Males \% body fat} = 86.010 \times \log_{10}(\text{abdomen} - \text{neck}) - 70.041 \times \log_{10}(\text{height}) + 36.76$$

$$\text{Females \% body fat} = 163.205 \times \log_{10}(\text{waist} + \text{hip} - \text{neck}) - 97.684 \times \log_{10}(\text{height}) - 78.387$$

The equations are derived from the Hodgson and Becketts (1984) prediction of percentage of body fat for U.S. Navy men and women at the U.S. Naval Health Research Center. The predictions of the female fat percentage estimation are based on a sample of 214 of female Navy soldiers aged 18-44 years (mean age of 26.5 years). The prediction equations for male fat percentage were based on 602 male Navy personnel aged 18-56 years (mean age of 31 years). Therefore the body fat percentage predictions for the U.S. Army represents a specific subset of population U.S. Navy personnel. The U.S. Navy personnel recruited for the sample were from the land-and shore-based commands representing active duty personnel (a specific population). These equations are used to measure the body fat percentage of ROTC cadets which is a generalized population; hence using these standards is not the best method to measure their body composition.

Based on these calculations the APFT norms establish a standard that is the maximum allowed body fat percentage for the ROTC cadets (Table 2).

Table 2. *Maximum Allowable Percent Body Fat Standards*

|                                 |
|---------------------------------|
| <b>Age group: 17–20</b>         |
| <b>Male (% body fat): 20%</b>   |
| <b>Female (% body fat): 30%</b> |
| <b>Age group: 21–27</b>         |
| <b>Male (% body fat): 22%</b>   |
| <b>Female (% body fat): 32%</b> |
| <b>Age group: 28–39</b>         |
| <b>Male (% body fat): 24%</b>   |
| <b>Female (% body fat): 34%</b> |
| <b>Age group: 40 and older</b>  |
| <b>Male (% body fat): 26%</b>   |
| <b>Female (% body fat): 36%</b> |

Note: Table copied from U.S. Department of the Army, Army Regulation 600-9 (2013).

U.S. Army Regulation 600-9 published in June 2013 reflects newly adopted practices of the U.S. Army to measure the physical fitness of the soldiers that further emphasizes the importance of body composition (U.S. Army Regulation: 600-9, 2013). The 600-9 regulation has increased the frequency of screening to six months using the circumference –based tape measurements for all active duty soldiers. If the soldiers exceed the required body fat standard they are placed in the Army Body Composition Program (ABCP) for continuing assessment and fitness training (U.S. Army Regulation: 600-9, 2013). In ABCP the soldiers are provided with exercise guidance, nutrition counseling by registered dieticians (if available), and help with behavior modification. The soldiers in ABCP are screened monthly for changes in body weight. An expected loss of three to eight pounds in a month is considered safe and satisfactory progress (U.S. Army Regulation: 600-9, 2013).

**Circumference-based tape measurement method.**

The circumference-based tape measurement used by ROTC uses a specific technique detailed in the 600-9 regulation (Appendix A). The highlights of the technique are that a trained individual is required to take the measurements of the ROTC cadets; measurements are not taken consecutively from the same spot to eliminate bias created by assumption of the value; and

cadets are required to wear a specific uniform when the measurements are being taken to facilitate efficient measurement.

The circumference-based tape measurement requires that measurement sites be located correctly and that the same amount of tension is applied every time a site is measured. Inter-observer error is also minimized as there are fewer steps that depend on the skills of the technician compared to the skin fold measurement technique. Circumference measurement is preferred over skin fold measurement technique on obese individuals because the skin fold measurement technique uses calipers that have limited width. However the circumference-based measurement will produce consistent results in lean individuals as the chances of technician error in the form applied tension during measurement (Heyard, 2001).

A study was conducted on 31 college-age Caucasian men aged between 20-25 (mean age = 22.5years) to determine the validity of various body composition measurement methods using two compartment model to a three compartment model. The two compartment model divides the body into FM and FFM whereas the three compartment model further subdivides the FFM into water, mineral and protein components (Brodie, Moscrip, & Hutcheon, 1997). The methods tested were hydrostatic weighing, ADP, near infrared interactance (NIR), bioelectrical impedance (BIE), and the circumference measurements used by Marine Corps, Army, Navy and Air force. The acceptable total error value was 4%. The results indicated that ADP (BOD POD), and hydrostatic weighing had the lower total error values of 2.7% and 2.5% as compared to other methods. The circumference-based measurements had the following error rates: Marine Corps – 4.7%, Navy and Air Force – 5.2%, Army – 4.7% and NIR had an error rate of 5.1%. These results indicate that the lab methods of BOD POD and hydrostatic weighing are more precise in calculating the body fat percentage (Moon et al., 2008).

The minimal amount of fat required for normal physiological function (essential fat) is 3% for women and 12% for men. Any amount of fat above this is called “non-essential fat”.

The generally accepted range is 10-22% for men and 20-31% for women (Esmat, 2012).

#### **Skin fold body fat estimate method.**

The most commonly used method for measuring body composition is skin fold (SKF) thickness measurement. SKF measurement is an indirect measure of body fat percentage as it uses the thickness of subcutaneous tissue to determine the fat percentage. Various equations have been developed to use this method which involves three sites or seven-site measurement. The raw data are then entered into the equations developed by Jackson and Pollock (1978) for men and Jackson and Pollock (1980) for women.

The skin fold measurement uses calibrated calipers to measure fat tissue thickness when pulled away from specific anatomic landmarks. The details of the technique is explained in Appendix B.

**Figure 1.** Skin fold measured using the caliper.



Note: Figure copied from Lee Hayward (n.d.) website.

This methodology is used commonly because it is an easy, quick, inexpensive, noninvasive method, and it predicts the body fat very accurately.

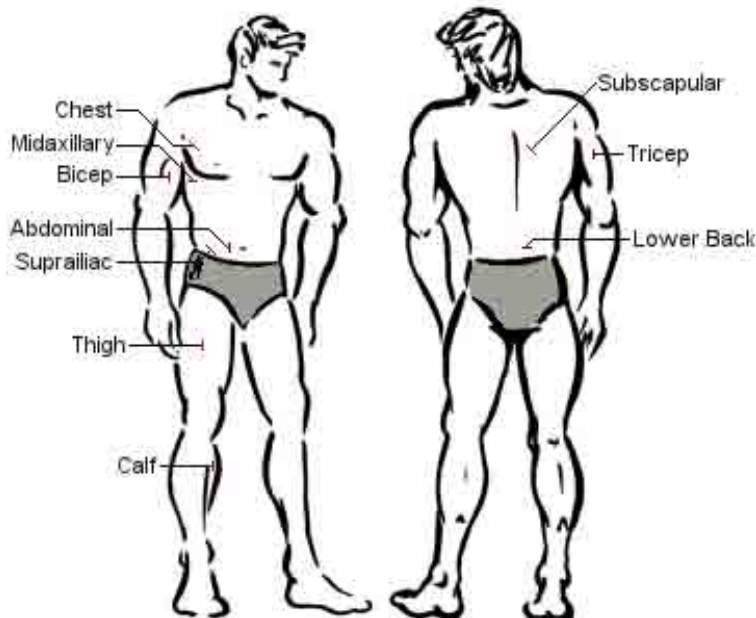
This method does require expertise by the person measuring the skin fold thickness. Measuring the correct site for skin fold thickness, pinching the right amount and type of underlying tissue, using the right caliper and proper equation are all important steps that examiner should keep in mind when conducting skin fold measurements. There are higher chances of intra observer error at various steps in this testing method resulting in varying results of body fat percentage for the same individual if tested by different examiners (Heyward, 2001). The other limitation of the skin fold measurement technique is that the caliper jaws have a limited width which can pose a problem when measuring skin fold for obese persons resulting in inaccurate measurements of body fat percentage. Skin fold should not be measured immediately after exercise as it can result in an overestimation of body fat due to the accumulation of edema in subcutaneous tissue (Heyward, 2001).

Jackson and Pollock (1978) sampled 308 men ranging from 18 to 61 years of age with wide range of body structure, composition and exercise habits. Multiple regression equations were calculated to estimate body density using a sum of skin folds, in combination with age and waist and arm circumference. These equations were cross-validated on a second sample of 95 men. Two kinds of predictive equations were calculated and created based on the age group of the samples. One was a generalized equation which provided valid and accurate body density estimates for with adult men varying in age and body fat (Jackson & Pollock, 1978).

***Pollock's seven-site skin fold measurement technique.***

The seven sites measured in this method are chest, axilla, triceps, subscapular, abdomen, supra-iliac, and thigh.

Figure 2. Measurement sites for the seven-site Pollock method.



Note: Image copied from Linear Software website (n.d.).

The Jackson and Pollock (1978) measurement technique was developed under the assumption that when an individual gains weight it is reflected by an increase in skin fold thickness. Body density is then converted into body fat percentage (%BF) using a two compartment model equation by Siri (1961):  $\%BF = (495 \div Db) - 450$  (Howley & Thompson, 2012).

The formula used for the conversion of body density to body fat percentage is  $BD = 1.11200000 - 0.00043499(x) + 0.00000055(x)(x) - 0.00028826 (A)$ . Where  $x$  = Sum of chest, axilla, triceps, subscapular, abdomen, supra-iliac, and thigh skin folds (mm) and  $A$  = Age in years.

The Jackson and Pollock (1978) measurement are extensively validated to measure body composition on several samples in male and female athletes and children with an accuracy between  $\pm 3.5\%$  body fat (Heyward, 2001).

The Jackson and Pollock equations were introduced in 1978 and using it on the current population can result in an under estimation of the body fat (Nevill et al., 2008). Skin fold thickness measurement using Jackson and Pollock equations gives inaccurate measurements in high percent body fat men and women (Peterson, Czerwinski, & Siervogel, 2003), Hispanic men and women and African American men (Jackson, Ellis, McFarlin, Sailors, & Bray, 2009), healthy Chinese adults (Eston, Fu, & Fung, 1995), and obese Brazilian women (Bottaro, Heyward, Bezerra, & Wagner, 2002).

### ***Gender differences.***

A quasi experimental study was conducted on college track and basketball athletes using the inclusion criteria from National Collegiate Athletic Association (NCAA) on a female sample. The results indicated that skin fold measurement was more accurate and correlated better with ADP when compared to BIA and DEXA (Shim, Cross, Norman, & Hauer 2013). Another study indicated that there is a higher chance of intra- and inter-observer error when measuring body fat percentage in men compared to women. This could be the result of difference in skin fold compressibility between men and women (McRae, 2010). Hence if skin fold is being considered as a method to determine body fat percentage then these small changes and errors should be taken into consideration.

### **Air Displacement Plethysmograph (ADP)**

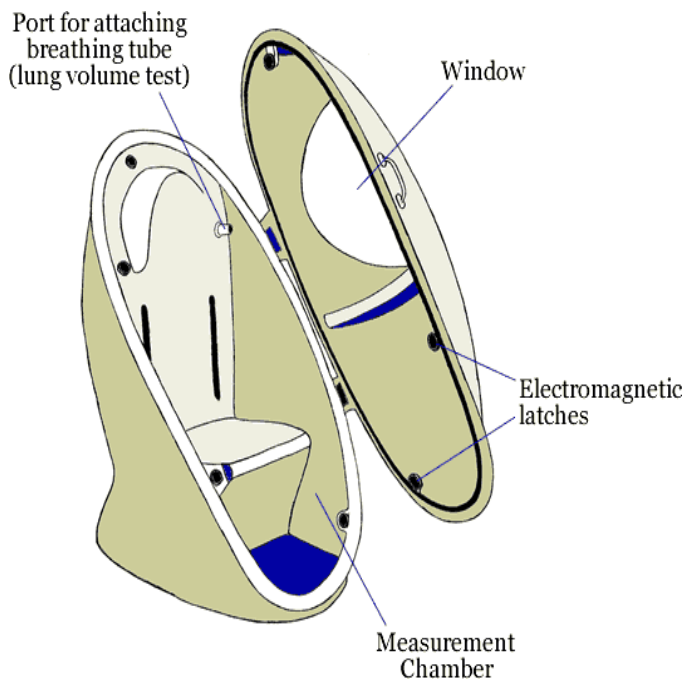
Various traditional body composition assessment methods have been used in the past 50 years includes hydro densitometry, helium dilution, air displacement plethysmography and acoustic plethysmography. Hydrodensitometry was pioneered by Behnke in 1942 and is the most commonly used densitometric method. This method uses the Archimedes Principles, which states “Volume of the object is equal to the object’s loss of weight in water with appropriate



correction for the density of water” (Dempster & Aitkens, 1995). Plethysmographic methods calculate body weight by using a subtraction technique, where the body volume is equal to the reduction in the volume of the chamber by the introduction of the subject. The plethysmographic methods require the subject to enter an enclosed space for the measurement which can cause changes in temperature and gas composition within the chamber. An understanding of the isothermal change is important for the success of plethysmographic methods.

Air displacement techniques introduced in 1963 by Gnaedinger were one of the earliest attempts at using ADP to measure body composition. It was not very successful as it produced measurement errors of 2.5%. However many advancements have been made in the use of ADP to measure body composition and two of the most commonly used systems are BOD POD and Pea Pod (Figure 3 & 4).

*Figure 3.* BOD POD is used for adults.



*Note: Image copied from*  
<https://www.bcm.edu/bodycomplab/bpodschemapage.htm>

*Figure 4.* PEA POD is used for infants.



*Note: Image copied from*  
[http://commons.wikimedia.org/wiki/File:Infant\\_body\\_composition\\_through\\_air\\_displacement\\_plethysmography.jpg](http://commons.wikimedia.org/wiki/File:Infant_body_composition_through_air_displacement_plethysmography.jpg)

BOD POD is a two chambered structure with a molded seat. A diaphragm is located on the common wall between the chambers which oscillates during the testing period. An air circulation system is used to mix the air between the two chambers so that air added in one chamber will be subtracted from the air in the other chamber (Dempster & Aitkens, 1995). The BOD POD produces very small volume changes and measures the body composition of the subject by calculating changes in pressure due to the small changes in volume.

These systems are produced by Life Measurement Incorporated (Concord, CA). These machines measure body density, measure or predict thoracic gas volume, and then use densitometric equations to calculate fat and fat free mass. The BOD POD software includes five equations to calculate body composition for specific populations (Table 3). Each of these equations was derived by testing the targeted population to accurately measure the body composition.

Table 3: *Population-specific Equations Included in BOD POD Software*

| <b><u>Name</u></b>   | <b><u>Equation</u></b>              | <b><u>Population</u></b>           |
|----------------------|-------------------------------------|------------------------------------|
| Siri <sup>1</sup>    | % fat = $(4.95/D_B - 4.50)*100$     | General Population                 |
| Schutte <sup>2</sup> | % fat = $(4.374/D_B - 3.928)*100$   | African American and Black Males   |
| Ortiz <sup>3</sup>   | % fat = $(4.83/D_B - 4.37)*100$     | African American and Black Females |
| Brozek <sup>4</sup>  | % fat = $(4.57/D_B - 4.142)*100$    | Lean and obese individuals         |
| Lohman <sup>5</sup>  | % fat = $(C1/D_B - C2)*100^\dagger$ | Children ≤ 17 yrs                  |

<sup>†</sup>C1 and C2 are constants based on age and gender

Note: Table copied from *BOD POD® Gold Standard Body Composition Tracking System Operator's Manual* (Life Measurement, Inc., 2010, p. 4)

**Requirements**

The detailed technique to measure body composition using BOD POD is explained in Appendix C. The key points for the measurement are various specifications required in the form

of room layout to store the machine, the specific clothing worn by the subjects, and the requirement of minimal movements by the subjects when the measurements are being taken. These specifications are required to be followed due to the sensitivity of the BOD POD to changes in air temperature and density (Hull & Fields, 2005).

The room layout includes specification in the for temperature range in the room which should be maintained within 70°-80° F and a relative humidity of 20-70%. The room is recommended to be of 8 x 8 ft in dimensions (Life Measurement, Inc., 2010).

The specific clothing requirements for the subjects include tight-fitting swimming attire including the swim cap. The reason behind this requirement is principles of physics that are associated with ADP, Boyle's Law, and Poisson's Law. These principles state that materials such as clothes are easily compressed and will result in (a negative volume) overestimating body density and underestimating body fat percentage (Moon et al., 2008). Various studies confer that when the subjects do not wear the manufacturer recommended clothing (Speedo like swim suit), it results in overestimating on body density (Hull & Fields 2005).

The limitation with using BOD POD as the body composition measuring technique is the formula used for conversion of body density to body fat percentage. Body composition has been validated to be used on various target groups like children, elderly obese people and few other ethnic groups. The factors that affect the accuracy of measurements include age, gender, physical activity, and ethnicity (Dempster & Aitkens, 1995). Due to these factors the BOD POD overestimates the percentage body fat of black men (20) and underestimated the body fat percentage of Division 1 Collegiate football players (Shim, 2014).

## **Methods**

Fourteen (14) ROTC cadets were recruited from the College ROTC programs at Central State and Cedarville Universities. All the participants were given the tour of the Human Exercise and Performance Laboratory (HEPL) and were informed about the body composition equipment and procedures. The participants had the opportunity to ask any questions about the research study and were required to complete the Internal Review Board (IRB) consent form to participate in the study. The approval to use human subjects was obtained from the IRB of Central State University.

### **Protocol**

Participants were required to complete a questionnaire asking them about their activity level. The activity level selections ranged from: Sedentary, Low Active, Active, and Very Active. Participants were then measured using ADP and the Pollock seven-site skin fold measurement method.

The participants were required to change in the tight fitting Speedo swimsuit as recommended by BodPod and wear a swim cap which was provided by the laboratory. The previously measured height was provided by the ROTC program for all the participants and the information was entered in the BOD POD. The body weight was measured to the nearest 0.01 kg using the BOD POD system electronic scale. The thoracic gas volume measurement used for all the participants were estimated using that function in BOD POD. Please view Appendix C in order to get the details of BOD POD testing. The percentage body fat was determined using the Siri equation (Siri, 1961).

Immediately upon completion of the BOD POD measurement the seven-site skin fold thickness measures were conducted for all the participants. The measurements were done by the

faculty Principal Investigator (P. Gupta) using a metal Lange caliper. The Jackson and Pollock (1978) seven-site formula was used to calculate the body fat percentage for all the participants.

Tape measurements were provided by the ROTC program using their standard form (DA form 5500).

**Data Analysis**

One sample t-tests and the Bland Altman Plot method (Bland & Atman, 2010) were used to compare the “best standard” ADP results with SFM and Tape Measurement results. Only one of the 13 participants was a female: that was considered an outlier for this study, so the female participant measurements were removed from the study. SPSS version 21 (IBM Corp. Released 2012) was used to conduct the analysis on de-identified data.

Descriptive statistics were generated and cadets’ adiposity from all the three measurement techniques were classified based on APFT and American College of Sports Medicine (ACSM) standards: 0= Risky (<5% Low Body Fat), 1= Ultra lean (5-8%), 2= Lean (8.1-12%), 3= Moderately Lean (12.1-20%), 4= Excess Fat (20.1-30%), 5= Risky (>30%).

**Results**

Table 4. *Descriptive Statistics for the Three Measurement Techniques*

|                       | Height | Weight | Age   | Tape Measur. | ACSM Rating | BodPod Fat % | ACSM Rating | SFM Fat % | ACSM Rating | Activity Level |
|-----------------------|--------|--------|-------|--------------|-------------|--------------|-------------|-----------|-------------|----------------|
| <b>Mean</b>           | 69.92  | 167.30 | 21.15 | 10.54        | 1.85        | 16.10        | 2.92        | 21.61     | 3.54        | 2.54           |
| <b>Std. Deviation</b> | 3.23   | 15.43  | 1.07  | 7.89         | 1.21        | 8.54         | 1.19        | 6.67      | 0.78        | 0.66           |

Table 5 illustrates one sample t-test comparing ADP and tape measurement. The p-value of .010 ( $p < 0.05$ ) indicated that the tape measurement results are significantly different from the ADP measurement.

Table 5. *One Sample T-test for ADP and Tape Measurements*

|             | t            | df        | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval |             |
|-------------|--------------|-----------|-----------------|-----------------|-------------------------|-------------|
|             |              |           |                 |                 | Lower                   | Upper       |
| <b>Diff</b> | <b>3.128</b> | <b>11</b> | <b>.010</b>     | <b>5.750</b>    | <b>1.70</b>             | <b>9.80</b> |

Table 6 illustrates one sample t-test comparing ADP and skin fold thickness measurement. The p-value of .002 ( $p < 0.05$ ) indicates that the tape measurement results are significantly different from the ADP measurement.

Table 6. *One Sample T-test for ADP and Skin Fold Measurements*

|             | t     | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval |         |
|-------------|-------|----|-----------------|-----------------|-------------------------|---------|
|             |       |    |                 |                 | Lower                   | Upper   |
| <b>Diff</b> | -4.11 | 11 | .002            | -5.6833         | -8.725                  | -2.6413 |

Figure 3 shows the Bland Altman graph for the tape measurement and ADP. The middle line represents mean. The Upper and the Lower Control limit are represent by  $\pm 2$  Standard Deviation from the mean.

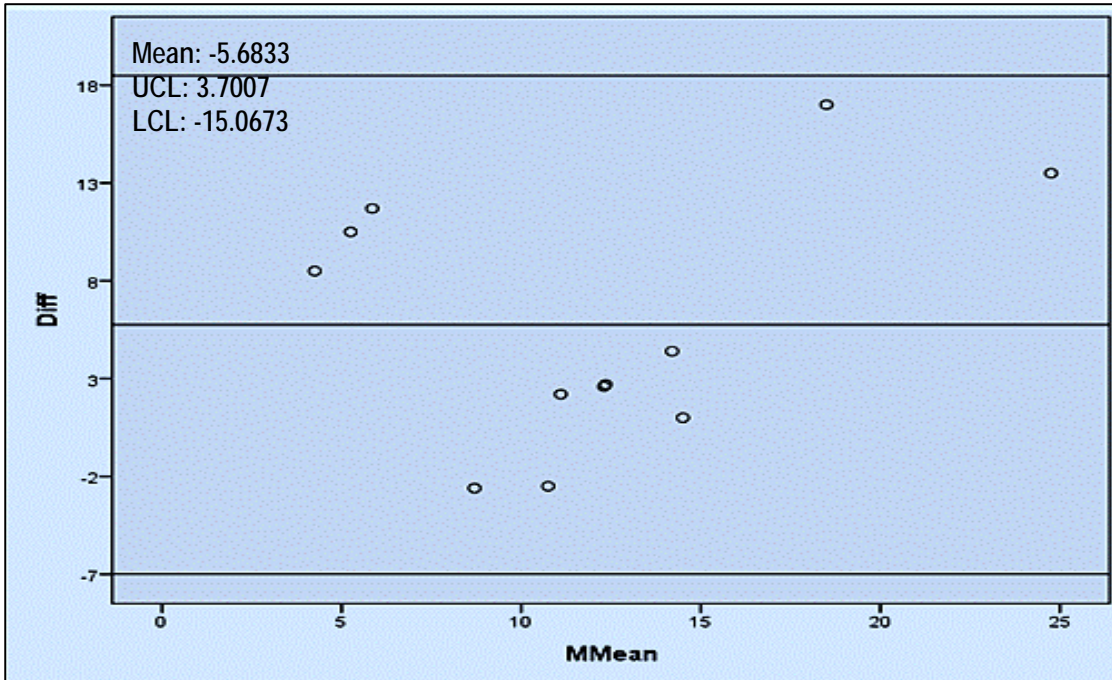


Figure 3. Scatter plot comparing the ADP measurements with tape measurements.

Figure 4 shows the Bland Altman graph for the skin fold measurement thickness and ADP. The middle line represents mean. The Upper and the Lower Control limit are represent by  $\pm 2$  Standard Deviation from the mean.

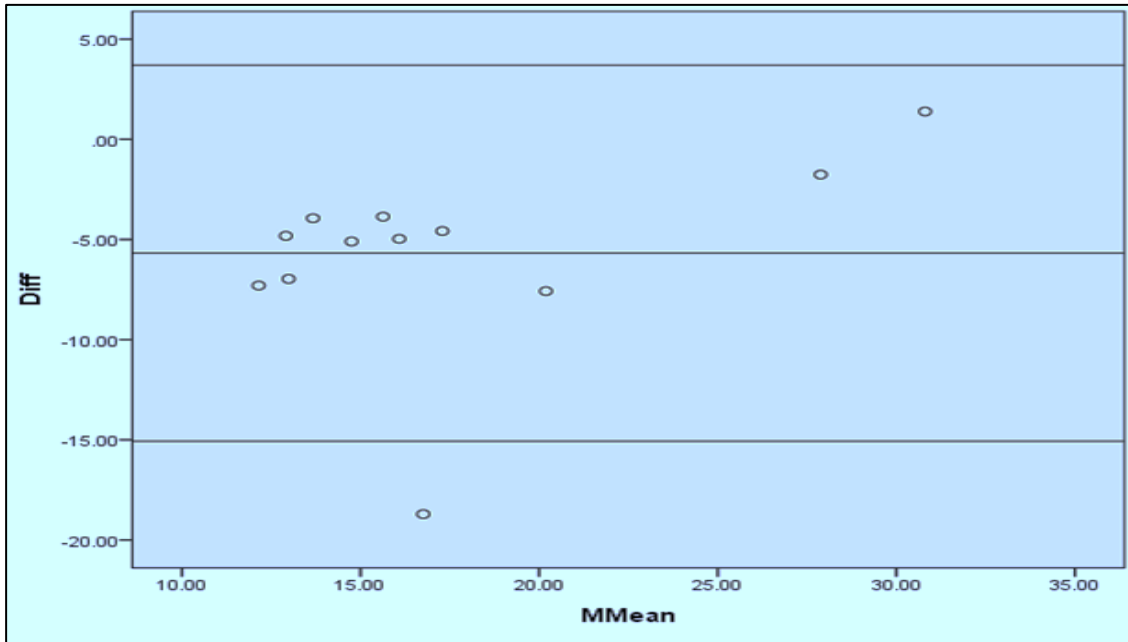


Figure 4. Scatter plot comparing the ADP measurements with skin fold measurements.

### Discussion

The descriptive statistics reveal that each type of measurements places the mean of participants in a different category on the ACSM rating. Tape measurement placed the participants at a mean 1.85 ACSM rating, between the 'Ultra Lean' and the 'Lean' category. The mean BOD POD measurement placed the participants at 2.92 ACSM rating, between the 'Lean' and the 'Moderately Lean' category. The mean skin fold measurement placed the participants at 3.54 ACSM rating, between 'Moderately Lean' and 'Excess Fat'.

The mean difference between skin fold measurement and ADP was negative, indicating that the skin fold method (significantly) overestimated adiposity. The mean difference between tape measurement and ADP is positive indicating that tape measurement (significantly) underestimated adiposity in this sample.

All cadets passed the criteria according to APFT testing but three individuals were classified as 'Risky' (low body fat) by tape measurement but as 'Lean' or 'Moderately Lean'



under the other two methods. The underestimation by tape measurement may introduce unnecessary concern and follow up, using limited resources unnecessarily.

From a practical stand point this study is important as it indicates that circumference based tape measurement can result in inaccurate estimation of the body fat percentage. The current U.S. Army regulations require the cadets and the active duty personnel to weigh in at least once every six months. Failure to pass the Army's minimum weight or body fat percentage standards will make the personnel ineligible for promotion, transfer, reenlistment or opportunities to attend professional schools. This can be a serious implication on the career of the personnel.

### **Limitations**

The limitation of this study is small sample size. The results from this study are by studying 12 participants. It is recommended to collect the data from a bigger sample.

### **Recommendations**

From these findings and similar results in the literature, we recommend the use of APD via BOD POD to measure body composition in ROTC cadets as the other two methods systematically underestimate or overestimate adiposity.

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## Appendix A

### Circumference-based Tape Measurement Technique

- The measurements are recorded by designated unit fitness trainers, certified master fitness trainers, and/or trained in body circumference methodology.
- 2 members are used to record the measurements, 1 placing the tape to measure and determine measurements and the other to ensure proper placement and tension of the tape and record the measurement in the DA form 5500/5501.
- The soldiers are usually measured by the individuals of the same gender with the soldier in the middle of the 2 individuals so that the tape is visible at all times.
- 3 measurements are recorded in a nonconsecutive fashion to make sure that there are no assumptions in the repeated measurements.
- If there is a difference of more than 1 inch from the other 2, an additional measurement is taken to add to the computational average.
- The tape is used such that it is in constant contact with the skin and conforms to the body surface being measured without any pressure or tension.
- Tape measure is made of non-stretchable material and compared with a yard stick or a metal ruler to ensure validity.

The Height and Weight Measurements also follow a unique technique:

Height:

- Soldier is measured in stocking feet, without running shoes, standing on a flat surface with head held horizontal and chin parallel to the floor.
- The soldier's height is measured and rounded to the nearest inch.

Weight:



- Soldier is measured in stocking feet, without running shoes.
- The weight is recorded to the nearest pound using the guidelines; if weight fraction is less than one-half pound, round down to the nearest pound and if greater than one-half pound, round up to the next whole pound.

Key Features of the ABCP program:

- Nutrition Therapy – Soldiers get guidance from a registered dietician to help lose weight without endangering the physical health of the individual.
- Increased Physical Activity – Soldiers are assisted with a physical trainer helping them to create an activity schedule to maintain healthy weight
- Behavior modification – This component helps in long term weight management.

Strategies like self-monitoring, stress management, planning and preparing are required for long term healthy weight maintenance.

## **Appendix B**

### **Skin Fold Measurement Technique**

- The subject is required to wear minimal clothing so that the skin fold can be measured
- A metal, lange, or plastic caliper is used to measure the skinfold.
- The seven sites for Jackson and Pollock (2004) is Abdominal, Thigh, Triceps, Subscapular, Suprailiac, Axilla and Pectoral.
- The investigator measures the skin folds for all the sites three times and an average of each site is used in the final calculation.

## Appendix C

### BOD POD Technique

- The subject is weighed on a calibrated scale and then a baseline calibration of the chamber is performed using 50-1 calibration cylinder.
- The subject then enters the chambers and sits down and the testing starts once the door to the chamber is closed.
- During the testing procedure the subject breathes ambient air in the chamber if the estimated Thoracic Gas Volume is used for measurements. The testing takes approximately 20 seconds and the door is opened once the testing is completed.
- A second testing immediately continues as soon as the door is closed to verify the first measurement. The subject is informed not to make any major movements during this time.
- If the two measurements agree within 150 ml, then the data is accepted and the mean value of the two measurements is used. If they do not agree within 150 ml then a third measurement is taken.
- If the three measurement also does not agree within 150 ml then the entire testing process is repeated, including calibration. If the Thoracic Gas Volume is to be measured then the subject is connected to the system's breathing circuit and a real time record of tidal breathing is recorded.

**Appendix D - List of Competencies Met in CE**

**Tier 1 Core Public Health Competencies:**

|   |
|---|
| <b>Domain #1: Analytic/Assessment</b>   |
| Use variables that measure public health conditions   |
| Use methods and instruments for collecting valid and reliable quantitative and qualitative data   |
| Identify sources of public health data and information  |
| Recognize the integrity and comparability of data   |
| Identify gaps in data sources   |
| Adhere to ethical principles in the collection, maintenance, use, and dissemination of data and information   |
| Describe the public health applications of quantitative and qualitative data  |
| Collect quantitative and qualitative community data (e.g., risks and benefits to the community, health and resource needs)  |
| Use information technology to collect, store, and retrieve data   |
| Describe how data are used to address scientific, political, ethical, and social public health issues   |
| <b>Domain #3: Communication</b>   |
| Participate in the development of demographic, statistical, programmatic and scientific presentations   |
| Apply communication and group dynamic strategies (e.g., principled negotiation, conflict resolution, active listening, risk communication) in interactions with individuals and groups  |
| <b>Domain #4: Cultural Competency</b>   |
| Incorporate strategies for interacting with persons from diverse backgrounds (e.g., cultural, socioeconomic, educational, racial, gender, age, ethnic, sexual orientation, professional, religious affiliation, mental and physical capabilities) |
| Recognize the role of cultural, social, and behavioral factors in the accessibility, availability, acceptability and delivery of public health services   |
| <b>Domain #5: Community Dimensions of Practice</b>  |
| Identify stakeholders   |
| <b>Domain #6: Public Health Sciences</b>  |
| Identify prominent events in the history of the public health profession  |
| Identify the basic public health sciences (including, but not limited to biostatistics, epidemiology, environmental health sciences, health services administration, and social and behavioral health sciences)                                   |
| Describe the scientific evidence related to a public health issue, concern, or, intervention  |
| <b>Domain #7: Financial Planning and Management</b>   |
| Describe the local, state, and federal public health and health care systems  |
| <b>Domain #8: Leadership and Systems Thinking</b>   |
| Use individual, team and organizational learning opportunities for personal and professional development  |

**Concentration Competencies:**

|  |
|--|
| <b>Public Health Management</b>  |
| Have a knowledge of strategy and management principles related to public health and health care settings                                       |
| Know effective communication strategies used by health service organizations   |
| Have an understanding of organizational theory and how it can be utilized to enhance organizational effectiveness                              |
| Have a knowledge of leadership principles  |
| Have an awareness of strategies for working with stakeholders to determine common and key values to achieve organizational and community goals |
| A knowledge of ethical principles relative to data collection, usage, and reporting results  |
| An awareness of ethical standards related to management  |
| Detailed knowledge of public health laws and regulations   |