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Obesity classification in military personnel: a comparison of body fat, waist circumference, and body mass index measurements

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Keywords: military personnel, obesity, body composition, body fat percentage, body mass index, waist circumference, ROC curves

ABSTRACT

Objective: To evaluate obesity classifications from body fat percentage (BF%), body mass index (BMI), and waist circumference (WC).

Methods: 451 overweight/obese active duty military personnel completed all three assessments.

Results: Most were obese (men=81%; women=98%) using National Institutes of Health (NIH) BF% standards (men>25%; women>30%). Using the higher World Health Organization (WHO) BF>35% standard, 86% of women were obese. BMI (55.5% and 51.4%) and WC (21.4% and 31.9%) obesity rates were substantially lower for men and women, respectively; $p<0.05$. BMI/WC were accurate discriminators for BF%-obesity (Θ for all comparisons>0.75, $p<0.001$). Optimal cut-points were lower than NIH/WHO standards; WC=100cm and BMI=29 maximized sensitivity and specificity for men, and WC=79cm and BMI=25.5 (NIH) or WC=83cm and BMI=26 (WHO) maximized sensitivity and specificity for women.

Conclusion: Both WC and BMI measures had high rates of false negatives compared to BF%. However, at a population-level, WC/BMI are useful obesity measures, demonstrating fair-to-high discriminatory power.

INTRODUCTION

For military personnel with fitness requirements, it is important to accurately determine body composition. High body fat percentage (BF%), or excess adipose tissue is of particular interest because it is related to increased morbidity and mortality risk (1). Dual-energy X-ray absorptiometry (DEXA) often is used as a reference method for body composition analysis and is considered the “gold standard” (2). DEXA is a multi-compartment model technique that examines both segmental and whole lean body mass and BF (2-3). However, the use of DEXA is costly and impractical for field use in large studies (2,4).

A comparable body composition measurement device is the Tanita foot-to-foot bioelectrical impedance analyzer. Besides body weight, the Tanita measures resistance to a small electrical current to estimate BF% (5). Tanita analyzers have compared favorably with DEXA ($r=0.94$, $p<0.001$) (5,6-7), and are inexpensive and simple to use in the field (8).

Other prediction techniques estimate body composition and BF distribution (5). For example anthropometric waist circumference (WC) measurements assess the regional distribution of BF. In one study (9), WC measurements correlated with BF mass for men and women and with BF% for women, but no associations were found between WC and BF% for men. In addition, the correlations between WC and trunk fat were higher than those between WC and total BF (9).

BMI, a ratio of weight to height, is commonly used in population studies. Although BMI is a simple and widely used estimate of weight status in population studies, numerous investigations have questioned its validity because it cannot distinguish between fat and fat free mass (e.g., 10 http://www.consumerfreedom.com/news_detail.cfm?headline=2764,11). Individuals with greater muscle mass, such as athletes and military personnel, may be classified as overweight or obese, while individuals who have excess fat, but not excess weight may be misclassified as having lower health risks based on their misleading ‘healthy’ BMIs. The rate of false negatives also increases with age, as older individuals tend to have higher body fat percentages than younger individuals with the same BMI (12-13).

Often WC or BMI measurements are used to screen for overweight and obesity in military personnel (14). Individuals exceeding measurement thresholds may have to undergo retraining programs or even dismissal (8). Because military populations are more active and younger than the general population, the validity of BMI for categorizing obesity and estimating BF% has been questioned (15). The purpose of this study was to evaluate the relationships between bioelectrical impedence determined BF%, WC, and BMI determined obesity in a military sample.

METHOD

Participants

A total of 451 participants were recruited and randomized in the parent weight gain prevention clinical trial (16). Inclusion criteria for this study included the following: 1) within five pounds below or equal or exceeding their Maximum Allowable Weight according to USAF Weight and Height tables (AFI 40-502, which was deactivated when the new USAF Fitness Program [AFI 10-248]) went into effect in January 2004); 2) access to personal computer with Internet access; 3) plan to remain in the local area for one year; and 4) male or female between ages 18-55 years. Exclusion criteria included: 1) pregnant, breastfeeding, planning to become pregnant or became pregnant; 2) weight loss of >10 pounds in last 3 months; 3) use of a prescription or nonprescription weight-loss medication during the 6 months prior to screening; 4) on any military medical profile; or 5) meeting a specific exclusion such as history of myocardial infarction, stroke, or cancer in the last 5 years, diabetes, angina, and orthopedic or joint problems that would prohibit exercise. Study procedures were approved by the Institutional Review Boards of Wilford Hall Medical Center, Baylor College of Medicine, and U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland. All participants gave informed consent.

Measures

Demographics: Each participant was asked to complete basic demographic information to include rank, age, race/ethnicity, marital status, years of education, years of military service, and whether they planned to retire from the military after at least 20 years of service.

Body Fat Percentage Estimation –BF% was estimated using a field-based Tanita Body Composition Analyzer foot-to-foot with scale (Tanita corp., Tokyo, Japan). Each military member wore an approved uniform of the day or standard physical training uniform or gym clothes without shoes or socks. The National Institutes of Health (NIH) cut-points to indicate obesity were used (i.e., >25% for men and >30% for women) (17).

Waist Circumference – WC was measured with a Gulick tape according to procedures outlined in AFI 10-248 and DoD Instruction 1308.3 (Figure 1.) using standardized anatomical landmarks, i.e., the iliac creast and the umbilicus, for women and men (18). Cut-points of WC >88cm (35in) for women and WC >102cm (40in) for men were used to indicate obesity (18).

<<<<Figure 1>>>>

Weight and Height – Weight and height were assessed at military Health and Wellness Centers and followed the procedures outlined in AFI 40-502 (The Weight and Body Fat Management Program and DoD Instruction 1308.3). Height was measured with the military member standing on a flat surface without shoes. Weight also was measured in an approved uniform or gym clothes without shoes. Measurements were made on calibrated scales and recorded to the nearest pound.

Body Mass Index (BMI) – BMI was determined by dividing weight in kilograms by height in meters^2. Both the National Institutes of Health (NIH) and World Health Organization (WHO) have BMI guidelines estimating body fatness and corresponding with morbidity and mortality risks. Current NIH guidelines were used to categorize individuals with a BMI of 25 to 29.9 as overweight and those with BMIs ≥ 30 as obese (17). For women, the more liberal WHO cut-point of 35% was also used to indicate obesity (19).

Blood Pressure – Blood pressure was measured following the standard epidemiological protocol, i.e., five minutes of rest in a seated position and then three separate blood pressure measurements using alternating arms with a mercury sphygmomanometer separated by 2 minutes between each reading (20). The first reading was omitted and the last two averaged to obtain each subject's blood pressure. Participants had not smoked for at least one hour prior to the measurement session.

Statistical Analysis

Statistical analyses were performed using SPSS® (version 14.0; SPSS Inc., Chicago, IL, USA). Means ± standard deviation scores or percentages were calculated for all baseline demographic variables stratified by each obesity criterion (i.e., BF%, WC, and BMI) and gender. The NIH (17) obesity standards based on BF%, WC and BMI were used for the primary analyses. Additionally, we recomputed all analyses for women using the more liberal WHO standards presented by DeLorenzo and colleagues (21), i.e., BF% >35% for women, because these values more closely match the WHO standards for obesity (19). Sensitivity, specificity, rates of false positives, false negatives, and accuracy also were computed.

Receiver Operating Characteristic (ROC) curves were computed for WC and BMI using BF% as the criterion. ROC curves assess the ability of diagnostic or screening tests, such as WC and BMI, to correctly classify disease status or health outcomes. The area under the curve (AUC) is a quantitative method of evaluating test accuracy in discriminating between diseased or not (or healthy or not). Conventionally, the AUC (often expressed as Θ, or theta) is expressed as a single number and ranges from 0.5 (no accuracy) to 1.0 (perfect accuracy) (22-23). AUC Guidelines for any test are 0.5-0.7=none to low discriminatory power, 0.7-0.8=fair discriminatory power, 0.8-0.9=good discriminatory power, and > 0.9=high discriminatory power. Tests can be compared to one another on one criterion by examining their 95% confidence intervals for overlap or non-overlap with overlapping intervals indicating that the methods are statistically similar.

RESULTS

Table 1 provides data on the demographic characteristics of the men and women who participated in the study.

<<<<Table 1>>>>

On average, the sample consisted of an equal number of men and women in their early to mid thirties who were married, educated and planning to retire from the military. Over half of male participants were White, 15.3% were African American, 19.8% were Hispanic, 3.6% were Asian or Pacific Islander, and 3.6% were of other ethnicities, while 53.3% of female participants were White, 30.6% were African American, 11.8% were Hispanic, 1.3% were Asian or Pacific Islander, and 3.1% were of other ethnicities. Obesity classification by BF% (>25% for men and >30% for women using the NIH [17] standard) indicated that 81.1% of the men and 98.3% of the women were obese. Obesity prevalence estimates based on WC and BMI also are provided in Table 1.

Next, we examined obesity prevalence for women using the alternate and higher BF% cutoff (>35%) suggested by DeLorenzo and colleagues (21). Using this criterion, only 85.6% were classified as obese, rather than the 98.3% found using the more stringent NIH standard (17). Correlations between BF%, WC, and BMI were high and statistically significant for both men ($r_{BF\%-WC}=0.629$; $r_{BF\%-BMI}=0.759$; $r_{WC-BMI}=0.741$; all $p<0.001$) and for women ($r_{BF\%-WC}=0.626$; $r_{BF\%-BMI}=0.691$; $r_{WC-BMI}=0.665$; all $p<0.001$), respectively.

Obesity rates, as estimated by WC and BMI were much lower than those derived from BF% (see Table 1; $p<0.05$ for both women and men) In addition, a higher percentage of the men were classified as obese according to WC and BMI standards as compared to the women. For women, and to a lesser extent men, BF% tended to be somewhat high for the groups classified as obese using WC and BMI. For example, women designated as obese using BMI standards had an average BF% of 43.9% which exceeds the 40% BF% used to define morbid obesity (24).

As shown in **Table 2**, WC and BMI methods were accurate and statistically significant for discriminating between BF%-defined obesity.

<<<<Table 2>>>>

While WC only showed fair discriminatory power in men, it demonstrated high discriminatory power in women (i.e., $\Theta>0.900$). For both men and women, BMI displayed good discriminatory power for accurately predicting obesity, with both AUC (Θ) values exceeding 0.800. However, both methods were statistically similar as evidenced by the overlap in the 95% confidence intervals for each gender. The AUC also was computed using the alternate BF% criterion for women (i.e., >35%). As can be seen in Table 2, using this criterion, both WC and BMI demonstrated good discriminatory power and were statistically equivalent. However, in both men and women (using both BF% criterions), the cutpoints for WC and BMI for optimizing detection of obesity were somewhat lower than the NIH (17) standards. For example, for men, a WC=100cm and BMI=29 maximized both sensitivity and specificity (i.e., both >65%). For women, a WC=79cm and BMI=25.5 maximized detection of obesity using the NIH (17) BF% criterion while a WC=83cm and BMI=26 maximized detection using the alternate criterion of BF%>35.

The sensitivity, specificity, and accuracy of WC and BMI for predicting BF%-based obesity using the NIH (17) criterion and alternate standard for women (BF%>35%) are provided in **Table 3**. **Figure 2** presents the false positive and false negative rates.

<<<<Table 3>>>>

<<<<Figure 2>>>>

More non-obese men (BF% < 25%) were misclassified as obese using the BMI method than the WC method (35% vs. 21%). All non-obese women (BF% < 30%) were correctly identified as such by both methods (specificity = 100%). WC and BMI were not very accurate for correctly identifying obese subjects, especially obese women using the NIH standard for BF% (17). Specifically, 78% of BF%-defined obese women were misclassified as non-obese (i.e., false negatives) using BMI standards and 68% were misclassified as non-obese using WC standards. In BF%-defined obese men, 35% and 42% were misclassified with the BMI and WC methods, respectively. The proportion of men correctly identified as being obese or not obese using the WC and BMI methods was two- to three-fold greater than the proportion of women correctly identified; i.e., accuracy was 62.0% for the WC method in men versus 34.0% in women and 69.0% for the BMI method in men versus 23.0% in women. Using the alternate BF% standard of >35% for women (19) only minimally improved accuracy and sensitivity (see Table 3).

WC was an acceptable predictor of BMI-based obesity in men and women. As shown in **Figure 3**, only 26% of the men and 22% of the women were misclassified using WC to predict BMI-based obesity.

<<<<Figure 3>>>>

The percentages of individuals misclassified by WC compared to the BMI criterion were evenly distributed between false negatives (22.5%) and false positives (25.5%).

DISCUSSION

The purpose of this study was to examine relationships among BF%, WC and BMI in a sample of military personnel. Like similar investigations (e.g., 21), we found that both WC and BMI underestimated obesity compared with BF%. Whereas approximately 50% of men and 21% to 32% of women were classified as obese using WC or BMI methods, 80% of men and up to 98% of women were classified as obese utilizing the BF% cutoffs for men and women, respectively. This finding is more noteworthy when examined in light of the actual BF% values for the individuals classified as obese in this military sample, which tended to be high. In addition, this also is notable because the field method we used to determine BF% tends to underestimate BF% when compared with DEXA (7). This pattern of results indicates that regardless of method used to assess or estimate BF%, a significant number of the military personnel in this study had rates of excess body fat that put them at higher risk for cardiovascular disease and other obesity-related comorbidities.

Although both WC and BMI tended to underestimate obesity compared to BF%, both exhibited statistically acceptable discriminatory power for accurately predicting obesity in women and WC displayed fair discriminatory power for predicting obesity in men based on AUC statistics. Even so, 68% to 78% of BF%-defined obese women were misclassified as non-obese according to WC and BMI standards, respectively. Accuracy improved somewhat for men, with only 35% (WC) and 42% (BMI) misclassified. These results should inform policy or practice in how WC and BMI derived data are utilized. For example, concerns about the potential for false positives, or a high number of athletic individuals with low percentages of body fat being misclassified as obese in the military population, were not supported by our data. Rather, what emerged from these data, consistent with similar investigations, has been a higher rate of false negatives, or individuals whose weight to height ratio would suggest minimal risk for morbidity or mortality, but whose BF% suggests otherwise. This study also found that the cutpoints for WC and BMI for optimizing detection of obesity were lower than national standards, echoing previously stated concerns about the accuracy of these cutpoints specifically related to age, gender, and ethnicity (e.g., 4,12,14).

Although not ideal, both WC and BMI were statistically equivalent and reasonably accurate in predicting BF% obesity in the present study. Of the two, BMI is preferred from a field perspective because it is less intrusive (does not require subjects to remove or raise their clothing), is more comparable across studies (compared with WC, which can be measured in a number of different ways, yielding varied results), and is simpler to obtain and report (i.e., it does not require special training). The ideal field situation, however, may be to combine WC and BMI data to improve prediction (25).

The findings of this study should be considered in light of its limitations. First, the instrument used to measure BF% was the Tanita bioelectrical impedance measure, a good field measure (4), but not the “gold standard.” Second, the participants were not a random sample from the general military population, but rather a group active duty U.S. Air Force personnel who volunteered to participate in a weight gain prevention study. The results, therefore, may not generalize to the larger military population. Research also has shown differences to exist between BF%, BMI and WC for different genders, ages, and ethnicities (26-28). Future studies with larger samples would be able to conduct ROC analyses among racial subgroups in order to determine if differences exist in areas under the curve for different racial groups in the military.

In conclusion, BF%, WC, and BMI, were significantly correlated for both men and women, although obesity rates varied substantially depending on the method of determination. When using BF% as the criterion, obesity identified using WC and BMI was more accurate for men than for women. For this sample, optimal cutpoints for identifying obese men were lower than the national standards (WC=100cm vs 102cm, and BMI=29 vs 30), as were optimal cutpoints for identifying obese women (WC=79cm vs 88cm and BMI=26 vs 30). While both WC and BMI tended to underestimate obesity rates as compared to BF%, both are adequate for use in large clinical and population studies, with BMI being the preferred, less-intrusive method. Future research should examine a larger, more representative military sample using all three obesity measurements.

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Table 1. Demographic variables classified by gender.[1]

Men (N = 222)						
Variable	**Obesity classified by BF%[2]**		**Obesity classified by WC[3]**		**Obesity classified by BMI[4]**	
	No	Yes	No	Yes	No	Yes
Number (%)	42 (18.9)	180 (81.1)	108 (48.6)	114 (51.4)	100 (45.0)	122 (55.0)
Age (years)	36.1±8.0	35.1±6.4	**34.0±6.9**	**36.5±6.4**	35.2±7.0	35.4±6.5
Percent Caucasian	66.7	55.6	53.7	61.4	**67.0**	**50.0**
Percent Married	81.0	82.8	83.3	81.6	84.0	81.1
Percent with ≥ Some College	97.6	96.7	95.4	98.2	97.0	96.7
Percent Enlisted	69.0	77.8	79.6	72.8	76.0	76.2
Years of Service	13.8±7.9	13.9±6.3	**12.8±6.6**	**14.8±6.5**	13.6±6.8	14.0±6.2
Percent Planning to Retire from AF	76.2	86.0	81.3	86.8	85.0	83.5
BMI (kg/m^2)	**28.6±1.6**	**31.4±3.0**	**29.3±1.5**	**32.4±2.8**	**28.6±0.9**	**32.7±2.3**
Waist Circumference (cm)	**97.1±6.9**	**104.0±7.3**	**96.6±4.3**	**108.5±5.4**	**98.2±5.9**	**106.4±7.0**
Body Fat %	**23.3±1.7**	**30.6±4.3**	**26.8±3.4**	**31.6±4.9**	**26.1±2.7**	**31.8±4.7**

Women (N = 229)								
Variable	**Obesity classified by BF%[2]**		**Obesity classified by BF%[5]**		**Obesity classified by WC[3]**		**Obesity classified by BMI[4]**	
	No	Yes	No	Yes	No	Yes	No	Yes
Number (%)	4 (1.7)	225 (98.3)	33 (14.4)	196 (85.6)	156 (68.1)	73 (31.9)	180 (78.6)	49 (21.4)
Age (years)	30.5±6.0	32.5±7.7	32.3±9.1	32.5±7.4	32.0±7.8	33.5±7.2	32.1±7.7	34.0±7.3
Percent Caucasian	25.0	53.8	63.6	51.5	51.9	56.2	55.0	46.9
Percent Married	75.0	60.4	57.6	61.2	59.6	63.0	61.1	59.2

Percent with ≥ Some College	50.0	89.3	**93.9**	**88.8**	**92.9**	**82.2**	90.6	85.7
Percent Enlisted	75.0	81.3	69.7	83.2	**77.6**	**89.0**	**78.3**	**91.8**
Years of Service	9.6±6.4	11.5±6.4	10.0±7.1	11.7±6.2	10.8±6.4	12.8±6.2	**10.9±6.4**	**13.4±5.8**
Percent Planning to Retire from AF	33.3	75.9	68.8	76.4	73.4	79.5	**71.9**	**87.8**
BMI (kg/m^2)	**25.5±1.0**	**28.0±2.4**	**25.8±1.0**	**28.3±2.4**	**27.1±1.9**	**29.9±2.4**	**27.0±1.5**	**31.6±1.5**
Waist Circumference (cm)	**77.2±2.4**	**86.3±6.5**	**80.2±4.6**	**87.1±6.3**	**82.6±3.9**	**93.7±4.1**	**84.2±5.2**	**93.4±5.7**
Body Fat %	**28.8±1.0**	**39.7±4.0**	**32.6±2.0**	**40.6±3.3**	**38.1±3.9**	**42.5±3.4**	**38.3±3.6**	**43.9±3.5**

[1] Bolded values indicate statistically significant differences, $p<0.05$.

[2] NIH standards for obesity based on body fat (BF) percentage are >25% for men and >30% for women (17).

[3] NIH standards for obesity based on waist circumference (WC) are >88cm (35in) for women and >102cm (40in) for men (17).

[4] NIH standards for obesity based on body mass index (BMI) are ≥30 (17).

[5] Standards for obesity based on body fat (BF) percentage >35% for women suggested by DeLorenzo et al. (25).

Table 2. Area under the curve (AUC) using waist circumference (WC) and BMI as the predictors of body fat percentage-based obesity stratified by gender.

Men Using NIH[1] BF% Criterion				
Variables	**AUC[2] (SE)[3]**	**P-Value**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
WC	0.761 (0.040)	< 0.001	0.683	0.839
BMI	0.841 (0.034)	< 0.001	0.774	0.907
Women Using NIH[1] BF% Criterion				
Variables	**AUC[2] (SE) [3]**	**P-Value**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
WC	0.925 (0.033)	0.004	0.861	0.990
BMI	0.826 (0.069)	0.026	0.690	0.961
Women Using WHO[4] BF% Criterion				
Variables	**AUC[2] (SE) [3]**	**P-Value**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
WC	0.807 (0.037)	< 0.001	0.735	0.880
BMI	0.833 (0.029)	< 0.001	0.777	0.889

[1] NIH (17) standards for obesity based on body fat (BF) percentage are >25% for men and >30% for women.

[2] AUC=Area Under the Curve

[3] Standard Error

[4] Standards for obesity based on BF% are >25% for men and >35% for women (25).

Table 3. Specificity, Sensitivity and Accuracy using waist circumference (WC) and BMI as predictors of BF%-based obesity and using WC as a predictor of BMI-based obesity.

<table>
<tr><th colspan="4">Men Using NIH[1] BF% Criterion</th></tr>
<tr><th>Variable</th><th>Specificity[2] (%)</th><th>Sensitivity[3] (%)</th><th>Accuracy[4] (%)</th></tr>
<tr><td>WC as a predictor of BF%-based obesity</td><td>79.0</td><td>58.0</td><td>62.0</td></tr>
<tr><td>BMI as a predictor of BF%-based obesity</td><td>65.0</td><td>65.0</td><td>69.0</td></tr>
<tr><td>WC as a predictor of BMI-based obesity</td><td>75.0</td><td>73.0</td><td>74.0</td></tr>
<tr><th colspan="4">Women Using NIH[1] BF% Criterion</th></tr>
<tr><th>Variable</th><th>Specificity[2] (%)</th><th>Sensitivity[3] (%)</th><th>Accuracy[4] (%)</th></tr>
<tr><td>WC as a predictor of BF%-based obesity</td><td>100.0</td><td>32.0</td><td>34.0</td></tr>
<tr><td>BMI as a predictor of BF%-based obesity</td><td>100.0</td><td>22.0</td><td>23.0</td></tr>
<tr><td>WC as a predictor of BMI-based obesity</td><td>76.0</td><td>80.0</td><td>79.0</td></tr>
<tr><th colspan="4">Women Using WHO[5] BF% Criterion</th></tr>
<tr><th>Variable</th><th>Specificity[2] (%)</th><th>Sensitivity[3] (%)</th><th>Accuracy[4] (%)</th></tr>
<tr><td>WC as a predictor of BF%-based obesity</td><td>100.0</td><td>37.0</td><td>46.0%</td></tr>
<tr><td>BMI as a predictor of BF%-based obesity</td><td>100.0</td><td>25.0</td><td>36.0</td></tr>
</table>

[1] NIH standards for obesity based on body fat (BF) percentage are >25% for men and >30% for women.

[2] Specificity is defined as is the proportion of true negatives identified by the screening test divided by all those free of the disease or disorder.

[3] Sensitivity is defined as is the proportion of true positives identified by the screening test divided by all those with the disease or disorder.

[4] Accuracy is defined as the proportions of individuals correctly screened as having or not having the disease divided by the total sample population.

[5] Standards for obesity based on body fat (BF) percentage are >25% for men and >35% for women suggested by DeLorenzo et al. (2003).

Figure Legends

Figure 1. Not Applicable

Figure 2. ■ False Negative □ False Positive

Figure 3. ■ False Negative □ False Positive

Figure 1. Waist Circumference Measurement Procedure

A7.3.3. A seamstress tape measure will be used for the abdominal circumference.

A7.3.4. Member stands looking straight ahead, arms down to sides.

A7.3.5. Examiner is positioned at right side of the member.

A7.3.6. Measurement is taken on bare skin; examiner feels to locate the upper hipbone and tope of the right iliac crest.

A7.3.7. A horizontal landmark is located just above the uppermost border of the right iliac crest.

A7.3.8. The tape is placed in a horizontal plane around the abdomen at the level of this landmark. Examiner ensures that the plane of the tape is parallel to the floor and that the tape is snug, but does not compress the skin. Measurement is taken at the end of a normal respiration.

A7.3.9. Take the circumference measure three times and record each measurement to the nearest ½ inch. If any of the measures differ by more than one inch from the other two, take an additional measurement. Add the three closest measurements, divide by 3, and round down to the nearest ½ inch. Record this value as the abdominal circumference measure.

Measuring Tape Position for Abdominal Circumference.

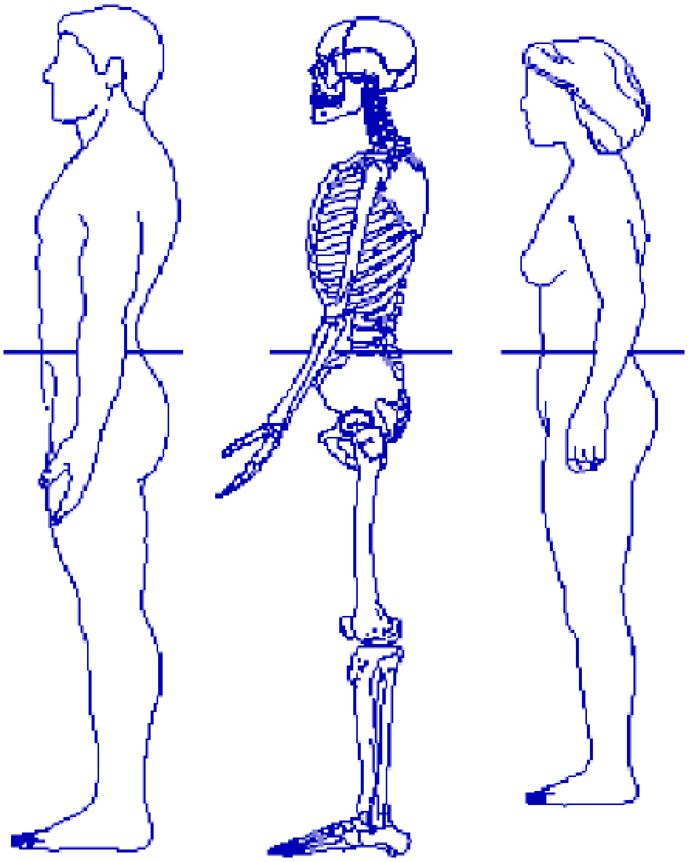
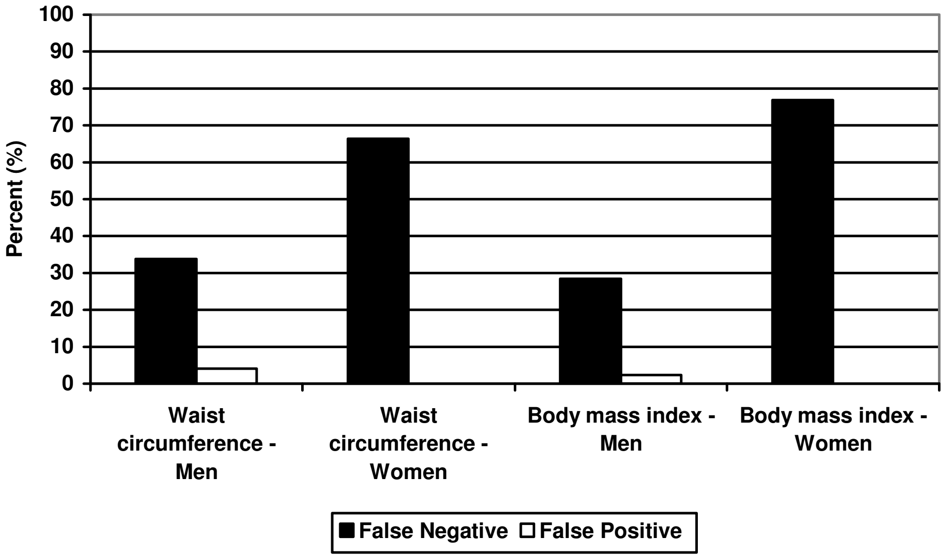
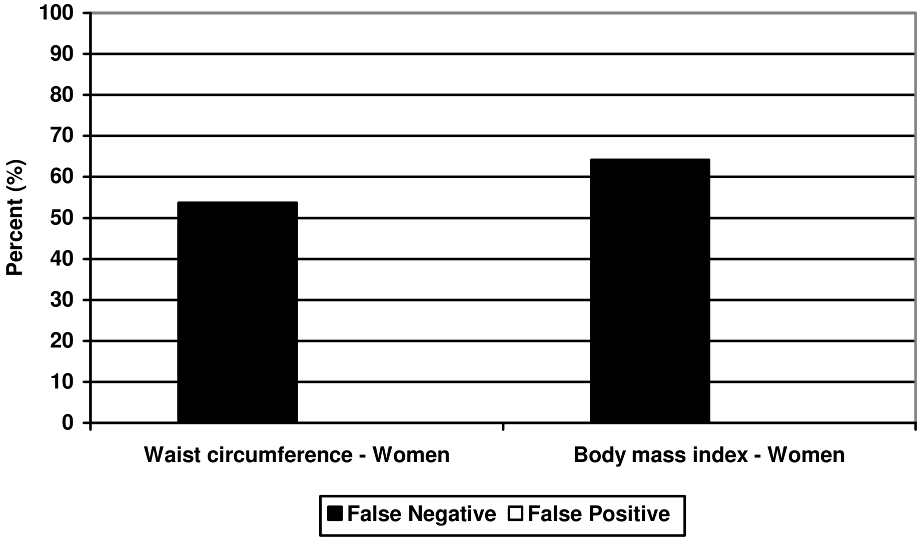


Figure 2. Percentage of false negatives* and false positives for the classification of obesity using waist circumference and body mass index with NIH body fat percentage as the criterion in military men and women and DeLorenzo et al. (2003) body fat percentage criterion for women only.**

NIH Body Fat Percentage Criterion



DiLorenzo etal. (2003) Body Fat Percentage Criterion for Women

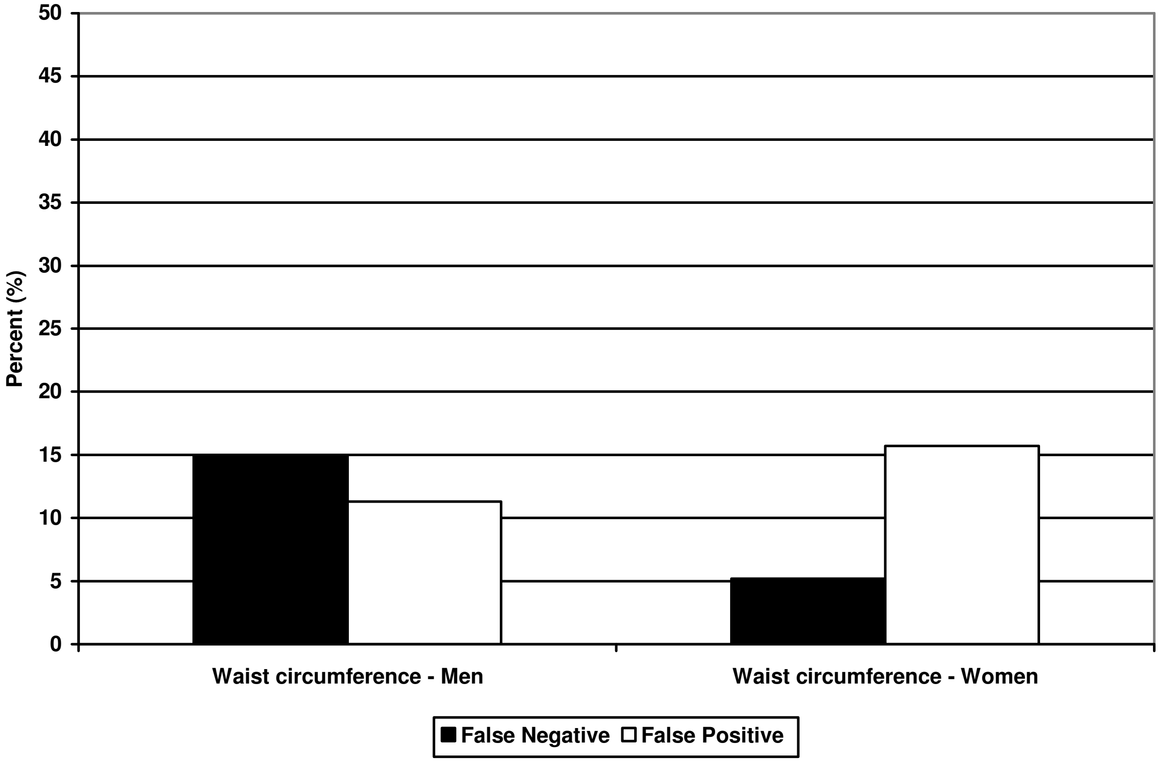


The study was conducted at a military medical and research center and three military bases in the Southwest US between the dates of June 2003 and October 2005.

*False negatives are defined as the proportion of individuals who have the disease but are screened as not having the disease.

**False positives are defined as the proportion of individuals who do not have the disease but are screened as having the disease.

Figure 3. Percentage of false negatives* and false positives for the classification of obesity using NIH waist circumference with NIH body mass index as the criterion in military men and women.**



The study was conducted at a military medical and research center and three military bases in the Southwest US between the dates of June 2003 and October 2005.

*False negatives are defined as the proportion of individuals who have the disease but are screened as not having the disease.

**False positives are defined as the proportion of individuals who do not have the disease but are screened as having the disease.