ABSTRACT

BAUER, S. R. Comparison of hydrostatic weighing to bioelectrical impedance analysis in women greater than thirty percent body fat. MS in Adult Fitness/Cardiac Rehabilitation, 1991, 55 pp. (J.Porcari)

Twenty-five female Ss age 18-65 years who had participated in a community weight loss class volunteered to have their body composition determined via hydrostatic weighing (HW) and bioelectrical impedance analysis (BIA). All subjects were greater than 30% body fat. It was discovered that bioelectrical impedance analysis using the BES 200Z analyzer significantly ($p<.05$) underpredicted percent fat in all 25 subjects, compared to HW. Percent fat predicted using the BES 200Z analyzer was poorly correlated ($r = .59$) to percent fat using HW. Mean percent fat determined by BIA was 33.9 ± 6.39 compared to 42.8 ± 6.30 using HW. Mean fat free mass (FFM) was significantly overestimated ($p<.05$) using BIA (54.8 ± 6.89) compared to HW (44.1 ± 6.80). New prediction equations were developed for the impedance analyzer. The highest correlation for a developed prediction equation was $r = .97$. This equation predicted FFM using the variables height squared (ht^2), weight, age, impedance (R), and waist-to-hip ratio (WHR). Further investigation needs to be done to validate the accuracy of this equation for the BES 200Z analyzer.

COMPARISON OF HYDROSTATIC WEIGHING TO BIOELECTRICAL IMPEDANCE ANALYSIS IN WOMEN GREATER THAN THIRTY PERCENT BODY FAT

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CHAPTER I

INTRODUCTION

Background

The prevalence of obesity is high in most Western societies (Lantz & Remington, 1990; Seidell et al., 1986). It has become an important health hazard and is associated with many common diseases that may increase morbidity and mortality (Bray, 1987; Gray, 1989; Manson et al., 1990; Seidell, Deurenberg, & Hautvast, 1984; Van Itallie, 1990). A few of these diseases and disorders are coronary heart disease (CHD), hyperlipidemia, diabetes, and hypertension (Folsum, Prineas, Kaye, & Soler, 1989; Gray, 1989; Manson et al., 1990; Remington & Moss, 1989).

A major problem with obesity is establishing valid tools for assessing body composition (Katch, 1983). The "gold standard", hydrostatic weighing (HW), assumes that the body has constant densities for fat and lean components. This assumption may not be true for obese individuals (Deurenberg, Leenan, Van der Kooy, & Hautvast, 1989).

In the past decade a number of new methods for the assessment of body composition have been developed. These include neutron-activation analysis, single-photon absorptiometry, computerized tomography, magnetic resonance imaging, total-body electrical conductivity (TOBEC), infrared spectrophotometry (Futrex 5000), and bioelectrical impedance analysis (BIA) (Eston, Brodie, Coxon, & Kreitzzman, 1989; Forbes, 1988; Lohman, 1984; Lukaski, 1987).

Many of these new methods of body composition analysis are expensive and available only in large medical facilities, thus making them impractical for widespread use. The latter method (BIA) is regarded as a valid method for measuring body composition, is relatively inexpensive, and can be applied in larger epidemiological studies (Baumgartner, Chumela, & Roche, 1990; Eston et al., 1989; Lukaski, Johnson, Bolonchuk, & Lykken, 1985). However, the BIA method has been found to overestimate percent fat in lean males and underestimate it in overweight males when compared to HW (Segal, Gutin, Presta, Wang, & Van Itallie, 1985).

The problem of determining body composition of obese subjects using BIA is that each instrument has equations for predicting body fat, which are preprogrammed by the manufacturer. Baumgartner et al. (1990) stated that a body composition tool is only as good as the prediction equation for that population. Very few prediction equations are available specifically for obese females. Colvin, Pollock, Graves, and Braith (1988) also showed that prediction equations determined by BIA are more accurate when applied to the impedance analyzer from which the data were taken. Thus, it is important to establish a prediction equation for obese women for each model of BIA.

Purpose

The purpose of this study was twofold. First was to compare BIA to HW for determining body composition of women whose body fat was greater than 30%. Second was to develop a prediction equation for the BES 2002 (Glassford, 1969) that would be valid in determining body composition of women who had greater than 30% body fat.

Need for the Study

Determining body composition on obese subjects is very difficult. Gray et al. (1990) discussed the inadequacy of determining body composition by skinfold thickness measurements. A new method, BIA, has been proclaimed as a good choice in determining body composition. However, a body composition tool is only as good as the prediction equation for the specific population tested (Baumgartner et al., 1990). Each manufacturer of BIA instruments develops prediction equations specific to that instrument. Very few prediction equations are available specifically for obese females using BIA. Further, prediction equations determined by BIA are more accurate when applied to the impedance analyzer from which the data were taken (Colvin et al., 1988). This study examined the validity and accuracy of using BIA in the determination of body composition in obese females and also developed prediction equations for obese women for the BES 200Z.

Hypotheses

The following hypotheses were tested in this study:

1. There will be no significant differences in body fat of obese females when measured by BIA and HW.
2. Prediction equations could be developed to accurately predict body composition in obese women using the BES 200Z BIA.

Assumptions

The following items were assumed in this study:

1. It was assumed that each subject refrained from food, caffeine, and tobacco for 4 hours prior to testing.

2. It was assumed that each subject had not exercised in the previous 24 hours.
3. It was assumed that each subject was not taking diuretics.
4. It was assumed that each subject was not near menses (4 days prior to onset and 4 days following).
5. It was assumed that each subject performed the test to the best of her ability.
6. It was assumed that each subject was in a normal state of hydration.
7. It was assumed that each subject was at her normal body temperature.

Delimitations

The following limits were placed upon this study by the researcher:

1. The sample consisted of 30 females, from the La Crosse, WI area, whose body fat was greater than 30 percent.
2. The subjects were between the ages of 18-65 years.

Limitations

The following were limitations inherent to this study:

1. The subjects were volunteers and not randomly selected.
2. The subjects did not consume identical diets prior to the testing sessions.

Definition of Terms

The following terms were used in this study.

Adipose Tissue - Tissue composed of approximately 80% fat, 18% water, and 2% protein, with a density of approximately .95 gm/ml (Pi-Sunyer, 1988).

Bioelectrical Impedance Analysis (BIA) - The instrument measures the body's resistance to a 800 uA current and uses this value to calculate body composition (Schulz, 1990). Bioimpedance is based on the fact that electrical energy flows easily through lean tissue, which contains the major portion of the body's water and electrolytes. The mass of the conductor is directly related to the length of the body and inversely related to the impedance (R). Fat is a poor electrical conductor and contributes very little to the R measurement. Fat quantity is obtained by taking the lean mass from the total body weight.

Bioelectrical impedance analysis uses a prediction equation to determine body composition. The variable commonly found in the equation is height squared divided by impedance (ht^2/R).

Fat - Tissue composed of practically all triacylglycerol and has a density of .9 gm/ml at 37^0 C (Pi-Sunyer, 1988). Fat is also anhydrous and potassium free.

Fat Free Mass (FFM) - Tissue having a density of 1.1 gm/ml at 37^0 C in the young to middle-aged adult, and is composed of approximately 72.5% water, 19.5% protein, 8% mineral, and 1-2% glycogen (Heymsfield & Williams, 1988). It also has a potassium content of 60-70 mmol/kg in men and 50-60 mmol/kg in women.

Hydrostatic Weighing (HW) - A process used as a basis for the determination of body density using the Archimedes Principle which states: An object immersed in a fluid loses an amount of weight equivalent to the weight of the fluid displaced (Lukaski, 1987). Hydrostatic weighing is also based on the two component model. The two components are body fat and lean body mass.

Impedance (R) - It is the frequency-dependent opposition of a conductor to the flow of an alternating electric current and is composed of two vectors, resistance and reactance.

Lean Body Mass (LBM) - It is synonymous with FFM.

Reactance - It is the reciprocal of capitance, or the storage of voltage by a condenser for a brief moment in time. It is small in most biological conductors, but may have considerable significance for the analysis of body composition.

Resistance - It is the pure opposition of the conductor to the current flow and is the reciprocal of conductance, or the ability of the object to convey an electrical current.

Total Lung Capacity (TLC) - The amount of air contained in the lungs at the end of a maximal inspiration.

$$TLC = IRV + TV + ERV + RV$$

Inspiratory Reserve Volume (IRV) is the amount of air which can be inspired above and beyond the normal tidal volume. Tidal Volume (TV) is the amount of air moved in and out with each breathe. Expiratory Reserve Volume (ERV) is the maximal amount of air which can be exhaled following a tidal expiration. Residual Volume (RV) is the amount of air remaining in the lungs after a maximal, forced exhalation.

Obesity - It is defined as greater than 20% body fat for men and greater than 30% for women (Gray, 1989).

Ohm's Law - A law stating that resistance is equal to the voltage divided by the current.

<u>Waist to Hip Ratio (WHR)</u> - It is the circumference in centimeters (cm) of the waist compared to the circumference (cm) of the hips, which determines abdominal fat distribution. Waist to hip ratio exceeding .80 to .85 for women and .90 to 1.0 for men have been cited as health risks (Gray, 1989).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The purpose of this study was to determine the accuracy and validity of BIA for determining percent body fat in obese women. The study was also designed to develop specific prediction equations for obese females using the BES 200Z BIA analyzer. This chapter was divided in the following manner. First, body composition assessment was discussed. Second, methods of body composition were addressed focusing on densitometry, HW equations, measurement of residual lung volumes, skinfold measurements, circumferences, BIA, and finally, prediction equations for BIA were discussed.

Body Composition Assessment

When discussing body composition, it is important to establish a reference body composition for males and females. In order to do this one must look at essential fat and storage fat. Essential fat is located in bone marrow, the heart, the kidney, the lungs, and the liver. This fat is required for normal physiological functioning. The essential body fat level for females was established from theoretical considerations and reported to include a sex specific quantity (principally found in the breast and pelvic regions). Essential body fat for women ranges between 5% to 12% of body weight and should not exceed 30% body fat (McArdle, Katch, & Katch, 1986). Above this level the women were considered obese. Essential body fat for males ranged from 3% to 7% and a body fat exceeding 20% was considered obese (McArdle et al., 1986; Peterson & Peterson, 1988; Yang, 1988).

Methods of Body Composition Analysis

A major consideration in body composition analysis is to choose an appropriate method. The ideal method for assessing human body composition should be relatively inexpensive, require minimal maintenance, entail a small inconvenience for the subject, be operable by unskilled technicians, and yield highly reproducible and accurate results (Garrow, 1982). The following sections discuss various body composition methods currently available.

Densitometry

Densitometry is associated with less technical error than other methods and is one of the two "gold standards" (energy-nitrogen balance being the other) against which the accuracy of other methods is often compared (Forbes, 1988). Inherent in the densitometric approach is the recognition of some fundamental assumptions. The chemical composition of FFM (bone, organs, and muscle) is assumed to be relatively constant so that the density of the FFM differs substantially from that of fat (1.1 vs. 0.9 gm/ml). Other assumptions include a constant level of hydration and a constant proportion of bone mineral to muscle in the fat-free body (Lukaski, 1987). These assumptions were questioned by Siri (1956), who emphasized the normal variation in water content as the largest single source of variability in the density of the fat-free body.

Lohman (1981), Lukaski (1987), Siri (1956), and Yang (1988) concluded that the variability in protein:mineral ratio could lead to a variation in percent body fat in healthy humans. Even if the experimental technique in assessing body density was error free, Siri (1956) states there would still be uncertainty in fat estimation (via densitometry) equal to ± 3.8% body fat. Assuming the error in specific population groups would be smaller than the population at large, Lohman (1981) calculates this error in estimated percent body fat in the former to be 2.7%. Forbes (1988) disputes the validity of choosing only one body composition method for the comparison standard. He states that while densitometry has the advantage of being subject to less technical error than other techniques, it was obviously impossible to determine accuracy for living subjects, and it is likely that the density of lean body mass varies with age and perhaps with sex.

Hydrostatic weighing equations. Hydrostatic weighing equations determine the body density. The body density must then be converted to body fat. Two widely used equations for the calculation of percent body fat from body density in adults were presented by Brozek, Grande, Anderson, and Keys (1963) and Siri (1956). Both of these equations were proposed for young adult men, based on cadaver chemical analysis (Lohman, 1984). Body fat values are very comparable when the body density ranges from 1.10-1.03 gm/ml, giving results within 1% body fat (Lukaski, 1987). However, for subjects with greater than 30% body fat, the Siri equation yields higher values than the equation of Brozek (Lohman, 1981).

Deurenberg, Leenan, Van der Kooy, & Hautvast (1989) stated that Siri's equation for predicting the body fat percentage from whole-body density will systematically overestimate the real body fat percentage by as much as 2-4% in severely obese subjects. Their article demonstrated that with an increase in body fat, the density of the FFM will decrease, caused by an increase in the relative amounts of minerals and protein.

Deurenberg, Westrate, and Van der Kooy (1989b) studied the use of Siri's equation in elderly obese women and found that it overestimated the real body fat percentage by 2-3%, depending on age. The reason for the overestimation is that in women, the loss of minerals during aging is considerably higher than the decrease in protein and water in FFM. As a consequence the change in chemical composition in FFM in females is remarkable, and therefore, the density (gm/ml) of the FFM decreases with age. Thus, the body fat percentage calculated from body density with Siri's equation overestimates the real body fat percentage.

In obese female subjects, especially the elderly, Siri's formula for the computation of the percent body fat from body density overestimates percent body fat by 2-4%. This overestimation is caused by an overestimation in the chemical composition of the FFM. Thus, Brozek's formula for the computation of the percent body fat may be a better choice.

Residual lung volumes. Residual volume (RV) has been the lung volume most widely used during HW because it is the volume least affected by hydrostatic pressure. However, one must be aware of the errors associated with residual lung volume estimates when making body density interpretation. Lohman (1981) has cited RV as the major source of error in the determination of density by HW. Marks and Katch (1986) showed that most of the error was attributed to biological variance

(81%) while technological error was 19%. The authors concluded that RV was an accurate measure to use when determining lung volumes.

It is important to emphasize the need to perform residual lung volume determinations at the same time of the underwater weighing. However, Wilmore (1969) showed no difference in mean body densities calculated from residual lung volumes determined during submersion, predicted from standard tables, or estimated from vital capacity measurements. All subjects were healthy, non smoking, physically active students. It is unlikely that a similar finding would be obtained with middle-aged males and females on whom hydrostatic forces would enhance exhalation during submersion (Lukaski, 1987).

Anthropometry

Skinfolds. The use of anthropometry for obtaining body fat estimates is well established and supported by empirical and theoretical evidence (Bray & Gray, 1988; Chumela & Baumgartner, 1989; Eston et al., 1989; Kushner & Hass, 1988; Lohman, 1984). The precision of a skinfold thickness measurement is dependent upon the anthropometrist and the site measured. In general, an approximate 3-5% body fat error is associated with using anthropometry to estimate densitometrically determined body fat (Lohman, 1981; Lukaski, 1987). Many equations are available for estimating percent body fat from skinfolds, but the validity of each equation is limited to the population with the same characteristics (age, sex, degree of fatness, and level of physical training) as that used in deriving the equation, (i.e., equations are population specific) (Lukaski, 1987; McArdle et al., 1986; Williams et al., 1990).

Jackson and Pollock (1985) stated that anthropometry is a method that requires little time, space, equipment, or financial outlay, and is fairly accurate in the clinical setting. Controversy still exists in the literature about the reliability of the skinfold measurement procedure. For example, differences in measurement can be caused by the caliper (Lohman, 1984) or by intra-investigator difference (Jackson, Pollock, & Ward, 1980; Lohman, 1981; Oppliger, Looney, & Tipton, 1987).

Few obese subjects have been included in studies to develop equations that estimate percent body fat from skinfold measurements (Lohman, 1988) and therefore it was questionable if these equations can be applied to obese individuals (Yang, 1988). Jackson and Pollock (1985) suggest prediction errors with their equations may be greater than expected in individuals who have a sum of skinfolds above the range found in their study population. Yang (1988) states that the table devised by Durnin and Wormsley (1974) may currently be the best for estimating percent body fat in the obese, since their subjects body fat measurements reached 46% and 53% in men and women, respectively (aged 16-72 years). This was provided that skinfolds were taken accurately at required sites. Unfortunately, bony landmarks used for site selection are more difficult to find in the obese and it is not possible to pull away a skinfold from the underlying tissue (Yang, 1988).

Circumferences. Several investigators have recommended the use of body circumferences in lieu of skinfold measurements for the assessment of body fat distribution (Deurenberg, Van der Kooy, Hulshof, & Evers, 1989; Forbes, 1990; Micozzi & Harris, 1990; Peiris et al., 1989; Tran & Weltman, 1989). Eston et al. (1989) compared circumference of the bust, waist, and hip to HW in females. The individual correlations were $r = .85$, $r = .91$, and $r = .91$, respectively. Since circumference measurements can be obtained in all obese subjects and are associated with less variability, circumferences may be preferable to skinfolds in the obese (Yang, 1988).

Another use for circumferences, and perhaps more important than their application in estimating percent body fat, is to determine the waist to hip ratio (girth ratio or WHR). The distribution of body fat may be more important than total body fat relative to the health risks associated with obesity (Bray & Gray, 1988; Gray, 1989; Seidell et al., 1984). While there is not universal agreement on the exact WHR cut-point establishing an "at risk" trunkal or abdominal fat distribution, WHR exceeding .80 to .85 for women and .90 to 1.0 for men are cited (Gray et al., 1990; Van Itallie, 1990).

Bioelectrical Impedance Analysis

When Cohn (1985) reviewed the BIA method, he found that professional opinion varies regarding its present applicability. For example, Gray (1989) states "Bioelectrical impedance analysis appears to be the first portable, reproducible, and easy to use method for determining body composition in patients with a wide range of body fatness."

The first BIA method was based on the principle that the lean body compartment contains a fairly constant ratio of water (72.5%) and conducting electrolytes which provide a good electrical pathway. By introducing a low frequency electrical impulse, one can measure the baseline resistance to flow of the current. The resistance measurement is then related to the volume of water in the conductor. The equations are then applied to predict FFM and total body fat (Khaled et al., 1988).

Lukaski et al. (1985) performed BIA and HW on 37 healthy young adult men whose body fat ranged from 8-43%. Test-retest correlation coefficient was $r = .99$ for a single resistance (R) measurement. Linear relationships were found between impedance (R) values and FFM ($r = .98$), total body water ($r = .95$), and total body potassium ($r = .96$). The authors concluded that the BIA technique is a reliable and valid approach for the estimation of human body composition. The authors did suggest that further validation of this method is recommended in subjects with abnormal body composition.

Deurenberg, Westrate, and Van der Kooy (1989a) compared the R values obtained from three identical instruments. Different readings were obtained when measuring the same subjects. These differences were statistically significant and presented a drawback of the method, especially when comparing results from other studies using different methods. These differences result in different prediction formulas published by several authors.

Also, Colvin et al. (1988) found that impedance analyzers from different manufacturers vary even after calibration. Therefore, it was recommended that R be measured using the same type of analyzer employed to develop the applied prediction equation.

Schell and Gross (1987) found that when testing for the R value the positioning of the electrodes is important for whole body measurements. Displacement of the source electrodes proximally by 1 cm, on either the hand or the foot, reduced the measured resistance by 2.1%; when both were displaced, the reduction was 4.1%. Schell and Gross also found that the limbs should be positioned so that they are not in contact with each other, and slightly separated from the trunk. However, abducting the arm on which the electrodes were attached from 30 to 90° from the trunk resulted in a 12 ohm, or 2% increase in resistance.

Prediction equations for bioelectrical impedance analysis. There have been several prediction equations that have been developed for BIA. Prediction equations have been developed for measuring total body water, FFM, and percent body fat. The resistance measured on the left side has been systematically different than the right. This difference is about 8 ohms. When developing prediction equations, the side on which R was measured must be stated.

Graves, Pollock, Colvin, Van Loan, and Lohman (1989) showed that different manufacturers impedance analyzers have varying results even after calibration. The authors recommended that participants should be measured using the BIA employed to develop the body fat prediction equation. The following are some of the prediction equations developed from height squared divided by resistance (ht^2/R) for FFM.

Lukaski et al. (1985) studied 37 men aged 19-42. The resultant regression equation developed was $3.04 + 0.85\ (ht^2/R)$ with a root mean squared error (rmse) of 2.6 kilograms (kg). The root mean squared error is the same as the standard error of the mean, which is a rough measure of the average amount by which sample means deviate from the population mean. Lukaski, Bolonchuk, Hall, and Siders (1986) developed regression equations for men and women. The study was done on 87 men and 64 women aged 18-50 years. The regression equation for the men was 5.21 + 0.83 (ht^2/R) with a rmse of 2.5 kg and, the regression equation for women was 4.92 + 0.82 (ht^2/R) with a rmse of 2.0 kg.

Chumela, Baumgartner, and Roche (1988a) and Cordain, Whicker, and Johnson (1988) included children in their sample sizes when developing regression equations. Chumela et al. (1988a) included 24 boys, 26 girls, 28 men, and 44 women in the study. The subjects' ages ranged from 9 to 62 years. Below are the regression equations developed:

Group	Regression Equation	rmse
boys	-1.23 + 0.92 (ht^2/R)	4.0 kg
girls	-1.38 + 0.96 (ht^2/R)	4.4 kg
men	3.50 + 0.87 (ht^2/R)	2.9 kg
women	11.55 + 0.69 (ht^2/R)	2.7 kg

Cordain et al. (1988) studied 14 boys with ages ranging from 9 to 14 years. The regression equation established for them was 6.86 + 0.81 (ht^2/R) with an rmse of 4.1 kg.

Guo, Roche, Chumela, Miles, and Pohlman (1987) developed a regression equation using variables from R and anthropometric variables. The authors included 77 males and 71 females in the study. The ages of the participants ranged from 18 to 30 years. The regression equations developed were as follows:

males	$1.5034 - 0.2790\ (ht^2/R) + 0.6316$ (tricep skinfold) $+ 0.3464$ (wt)
female	$-8.4773 + 0.4296$ (bicep skinfold) $+ 1.3405$ (calf circumference) $- 0.8450\ (ht^2/R) + 0.3833$ (wt)

Guo, Roche, and Houtkooper (1989) developed regression equations for males and females aged 7-25 years. The study included 140 males and 110 females. The regression equations were as follows:

males	$-2.9316 + 0.6462$ (wt) $- 0.1159$ (lateral calf skinfold) $- 0.375$ (midaxillary skinfold) $+ 0.4754$ (arm muscle circumference) $+ 0.1822\ (ht^2/R)$
females	$4.3383 + 0.6819$ (wt) $- 0.1846$ (lateral calf skinfold) $- 0.2436$ (tricep skinfold) $- 0.2018$ (subscapular skinfold) $+ 0.1822\ (ht^2/R)$

Segal, Van Loan, Fitzgerald, Hodgdon, and Van Itallie (1988) reported a multilaboratory comparison of FFM predictions from R and anthropometric variables in 1,567 adults. Each laboratory used body density to calculate FFM and used the prediction equations supplied by the manufacturers. These equations employed ht^2/R and weight as independent variables. The rmse were 3.7 kg for men and 3.2 kg for women with a systematic overprediction of about 5.2 kg for men and 2.7 kg for women. In other studies of the manufacturer's equations, Segal et al. (1985) found an rmse of 3.7 kg. Some other studies have shown that the manufacturer's equations underpredict FFM in lean individuals (Keller & Katch, 1985, 1986; Segal et al., 1985).

Segal et al. (1988) studied a population of 99 obese subjects with the goal of developing a specific equation to predict FFM in men with greater than 20 and women with greater than 30% body fat. The root mean squared errors were as follows; 2.4-2.5 kg for non-obese men, 3.0 kg for obese men, 1.0-2.0 kg for non-obese women, and 1.8-2.1 kg for obese women. These results confirm the validity of BIA's and indicate that the precision of predicting lean body mass from R can be enhanced by sex-and-fatness specific equations. The generalized and the fat-specific prediction equations that Segal et al. (1988) developed used the RJL-Systems BIA. The equations from this study are listed below.

GENERALIZED EQUATIONS

Men (r = .89; SEE = 3.61)

$FFM = 0.00132 (ht^2) - 0.04394 (R)$

$+ 0.30520 (wt) - 0.16760 (age) + 22.66827$

Women (r = .89; SEE = 2.43)

$FFM = 0.00108 (ht^2) - 0.02090 (R)$

$+ 0.23199 (wt) - 0.06777 (age) + 14.59453$

FAT-SPECIFIC EQUATIONS

Normal men (<20% fat) (r = .94; SEE = 2.47)

$FFM = 0.00066360 (ht^2) - 0.02117 (R)$

$+ 0.62854 (wt) - 0.12380 (age) + 9.33285$

Obese men (>20% fat) (r = .93; SEE = 3.03)

$FFM = 0.00088580 (ht^2) - 0.02999 (R)$

$+ 0.42688 (wt) - 0.07002 (age) + 14.52435$

Normal women (<30% fat) (r = .90; SEE = 1.97)

$FFM = 0.0006460 (ht^2) - 0.01397 (R)$

$+ 0.42087 (wt) + 10.43485$

Obese women (>30% fat) ($r = .95$; SEE = 1.97)

$FFM = 0.00091186\ (ht^2) - 0.01466\ (R)$

$+ 0.29990\ (wt) - 0.07012\ (age) + 9.37938$

Gray, Bray, Gemayel, and Kaplan (1989) cross-validated the results of Segal et al. (1988) in a different laboratory and to explore the validity of the method over a wide range of body-fat values. The RJL-Systems BIA was used. Gray et al. (1989) developed generalized prediction equations for men and women. These prediction equations are listed below:

Men ($r = .97$)

$FFM = 0.00139\ (ht^2) - 0.0801\ (R)$

$+ 0.187\ (wt) + 39.830$

Women ($r = .92$)

$FFM = 0.00151\ (ht^2) - 0.0344\ (R)$

$+ 0.140\ (wt) - 0.158\ (age) + 20.387$

Women (>48% fat) ($r = .96$)

$FFM = 0.000985\ (ht^2) - 0.0387\ (R)$

$+ 0.158\ (wt) - 0.124\ (age) + 29.612$

McCaughey et al. (1990), compared previously developed prediction equations of normal adult women to obese women. The authors found that the prediction equations for normal adult women overpredicted FFM by 7.8 kg in the obese. The authors then developed prediction equations specifically for obese females which are listed below.

	REGRESSION COEFFICIENTS Intercept	age	ht	wt	R	ht^2/R	r^2	SEE
OB-EQ1	-.18	.1088	.3251	.1970	.0331	-	.92	1.40
OB-EQ2	13.61	.1235	-	.2160	-	.4034	.92	1.44

These data indicate that FFM can be predicted from whole body resistance (R) in obese women but previously developed equations may not be appropriate. The authors state that a cross-validation of OB-EQ 1 and OB-EQ 2 were required before they can be used practically.

Most of the research presented in the literature using BIA has used the RJL-System analyzer (Gray et al., 1989; Segal et al., 1985, 1988).

The only prediction equation for the BES 200Z is the one developed by the manufacturer and is listed below:

$$LBM = 0.9951 \times (ht^2 / Z)$$

ht^2 = the height squared

Z = the R to flow

This simple equation developed by Glassford (1969) would overestimate the fat in the lean individual and underestimate the fat in the obese. Glassford has updated his equation but it was not available to this researcher.

Summary

Body composition can be determined many ways, such as skinfold measurements, circumferences, HW, and BIA. When determining body composition, it is important to use a tool that is applicable over a wide range of body fat levels. This becomes complex when dealing with the obese population because accurate skinfold measurements may be difficult to obtain at required sites (Yang, 1988). Circumferences have been shown to be a good indicator of body composition, since it was associated with less variability, making it preferable to skinfolds for the obese (Katch, 1983; Yang, 1988). Hydrostatic weighing has been an accurate determination of body composition but it may be difficult for an obese person to undergo the procedure (Lohman, 1981; Lukaski, 1987). Bioelectrical impedance analysis was an easy procedure for an obese person to undergo. It also appears to be a reliable and valid approach for the estimation of the percent body fat in obese and normal subjects (Gray et al., 1989; Lukaski et al., 1985; Segal et al., 1988).

Prediction equations have been developed by manufacturers and were built into the instrument. Usually these equations are generalized for the entire population but typically underpredict percent fat in obese subjects. This study proposed the development of specific prediction equations for obese women greater than 30% body fat using the BES 200Z.

CHAPTER III

METHODS AND PROCEDURES

Introduction

Methods were developed to assess the accuracy of determining body composition of women who had greater than 30% body fat. The items discussed are subject selection, development of methods, experimental procedures, development of the prediction equations, and statistical analysis of the data.

Subject Selection

The subjects used in this study were 30 volunteers from a community-based weight loss class held in La Crosse, WI. Each subject had to be greater than 20% of their ideal weight based on frame size according to the Metropolitan Life Insurance Height and Weight Tables (Metropolitan Life Insurance Company, 1983). This was determined the first day of the weight loss class. The ages of the volunteers ranged from 18-65 years. The participants were recruited by flyers placed in local grocery stores, area businesses, and in the La Crosse County office building. Each participant recruited for the weight loss class was given the option of being part of this study. Each participant was informed of the procedures, read and signed an informed consent document (see Appendix A), and completed a medical history questionnaire (see Appendix B) before beginning the study.

Development of Methods

A pilot study was conducted to determine the exact testing procedures. Ten female subjects between the ages of 31-60 years were tested. As a result of the pilot study, refinements of the experimental protocol were made.

Experimental Procedures

All participants reported to the Human Performance Laboratory at the University of Wisconsin-La Crosse for a 2 hour testing session. The participant signed an informed consent document and filled out the medical history questionnaire. Subjects had various anthropometric measurements were taken while wearing their swimsuit. Each subject then had a BIA value determined. Following this, RV determinations using an oxygen dilution method (Wilmore, 1969) were performed. Lastly, the HW procedure was completed.

Anthropometric Measurements

Height. Subjects stood with their backs to the wall-mounted height scale, feet together, and hands down to the side. With head erect facing forward, the sliding height arm was positioned on the top of the head. The height was recorded to the nearest cm.

Weight. Subjects stood barefoot on a Health-O-Meter scale with their weight evenly distributed. The weight was recorded to the nearest .25 kg.

Maximal abdominal girth. A girth measurement was taken at the maximal abdominal circumference using an Ohaus fiber glass 150 cm measuring tape. The measurement was taken over the swimsuit and recorded to the nearest .1 cm.

Maximal gluteal girth. A girth measurement was taken at the maximal gluteal circumference. The measurement was taken over the swimsuit using an Ohaus fiber glass 150 cm measuring tape and recorded to the nearest .1 cm.

Bioelectrical Impedance Analysis

Bioelectrical impedance was measured using the BES 200Z analyzer. The subject was placed in a supine position. To conduct the electrical current, four electrodes were placed on the right side of the body, two on each extremity. The wrist electrode was placed on the distal side of a line bisecting the prominent bone of the wrist and the other hand electrode was placed on the fingers. The ankle electrode was placed on the distal side of a line bisecting the lateral and medial malleoli that was prominent at that site. The other electrode was placed over the toes. The electrodes were placed over two or more digits on the fingers and toes to assure good contact of the electrode to skin (see Figure 1).

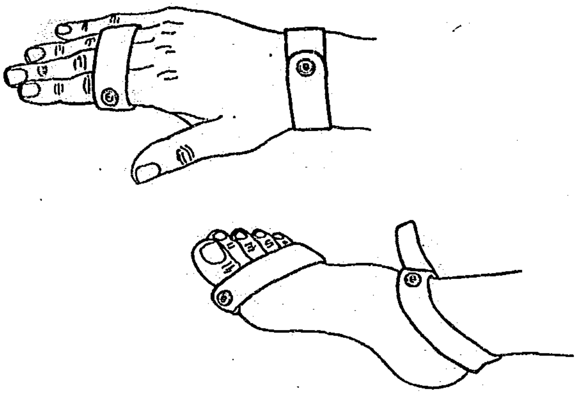

Figure 1. Placement of the Four Electrodes

A current of 800 uA at 50 KHz was introduced at the distal electrodes of the hand and foot. The voltage drop was detected by the proximal electrodes: the resistance value was used to calculate conductance (ht^2/R) and to estimate FFM. The current was undetectable, no shock hazard was present, and there was no known risk from this procedure.

The BES 200Z was designed to include an internal calibrator. An internal R of 510 ohms is measured when the TEST and RUN buttons were simultaneously pressed and held. The reading displayed should be within 1% of the internal R (505-515 ohms). This testing was done prior to the first test and then after every tenth individual to assure quality control.

Residual Volume

The subject sat in the HW tank with water at shoulder level. Determination of RV was done by the closed circuit oxygen dilution method (Wilmore, 1969). A fast responding electronic nitrogen analyzer (Collins, nd) was used to continuously sample the gas being respired at the subject's mouth and the nitrogen content was recorded during the maximal exhalation and subsequent rebreathing by a chart recorder (Med-Science Electronics, 1985). The calibration of the nitrogen analyzer and chart recorder was checked after each subject.

Six L of oxygen was selected as an appropriate volume for the rebreathing procedure to follow Before each RV trial a rebreathing bag was repeatedly flushed with oxygen, emptied with a vacuum pump, and then filled with the predetermined oxygen volume. During all rebreathing procedures the subjects were seated. When an audible signal was given by the tester the subject initiated a forced expiratory maneuver which had been previously demonstrated by the tester. Each subject was asked to minimize body movement during the forced expiratory effort and, after expelling as much air as possible, to signal by raising the right index finger. Immediately after this signal was given by the subject, the valve connecting the respiratory hose to the rebreathing bag was opened. A second audible signal by the tester cued the subject to commence deep and rapid rebreathing of oxygen. Each subject continued deep and rapid ventilations until a relative equilibrium was attained with respect to the nitrogen content of the respired gas. Based on the closed circuit oxygen dilution method the following equation was used to calculate residual volume (RV):

$$RV = VO_2(EN_2 - IN_2)/(AN2 - FN_2) - DS \times 1.1$$

VO_2 = Initial bag volume in system
AN_2 = Initial percent of nitrogen in alveolar air
IN_2 = Impurity of oxygen
EN_2 = Percent nitrogen in equilibrium
FN_2 = Percent nitrogen in alveolar air at end of test
DS = Dead space of mouthpiece and area containing nitrogen sensing needle

Hydrostatic Weighing

Electronic load cells fastened to the HW chair were used to determine the weight of the subject underwater. Load cells bend slightly under the stress of the subject's weight. The change in the resistance through the load cells is used to calculate body weight. Once in the tank, the subject was instructed to kneel down and remain motionless so the computer could calibrate the HW chair. Once the water was still, the computer determined calibration at 0 kg. The subject remained in the same position and 2 kg weights were placed on each side of the chair. The load cell was then calibrated to the new weight of the chair (4 kg). The subject was seated after the 4 kg weight was removed from the chair.

A weight belt (4 kg) was placed over the lap of the subject. An effort was made by the subject to remove all air bubbles that had accumulated in the their swim suits or hair. With their feet on the bottom rung and gently grasping the side of the chair, they were instructed to exhale maximally and slowly lean forward pulling the upper body down towards the thighs until the head and body was completely submerged. The subject was then instructed to indicate to the tester when all their air had been expired using a "thumbs-up" indication. The subject remained submerged until the reading had been displayed on the computer (approximately 2 seconds). A minimum of six trials were given to allow the subjects to get accustomed to the procedures and determine an accurate underwater weight.

Computation of Body Density and Percent Fat

Based on HW the following equations were used to determine body density and percent fat. The value of the underwater weight was determined by subtracting the weight of the belt (4 kg) from the total weight. This was subtracted before the new value was imputed into the computer to compute the body fat.

BD = Body density
MA = Mass in air
MW = Mass of water displaced
DW = Density of water
RV = Residual volume

$$BD = \frac{MA}{\frac{MA - MW}{DW}} - RV - .1L$$

Brozek et al. (1963):

$$\text{Percent Fat} = (4.57/BD - 4.142) \times 100$$

Development of the Prediction Equations

Prediction equations were developed to determine FFM and also percent body fat. The variables used for the prediction equation were age, height^2, R, WHR, and ht^2/R. From these variables, a multiple regression analysis was performed using the Math Statistics Program (Ytse, 1982).

Statistical Analysis

Paired t-tests and a Pearson product-moment correlation were used to determine potential differences in body fat and FFM as determined by BIA and HW. Multiple regression analysis was used to develop a regression equation for prediction of body composition using the BES 200Z BIA. The following variables were used: height, weight, age, R, ht^2/R, and WHR. Statistical significance was set at $p<.05$ for all analyses.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was twofold. First was to compare BIA to HW for determining body composition of women whose body fat was greater than 30%. Second was to develop a prediction equation for the BES 200Z BIA that would be valid in determining body composition of these women. The results of this study were separated into two sections. The first compared BIA to HW and the second part dealt with the prediction equation. The level of statistical significance was established at the .05 level for all analyses.

Results

Subject Characteristics

Thirty subjects from a community weight loss class volunteered for body composition analysis. Five participants failed to complete the testing. Two of the five subjects did not follow the proper protocol for the testing and the other three were unable to complete the HW procedure. Descriptive data of the subjects who completed the testing are presented in Table 1.

Table 1. Descriptive Characteristics of the Subjects (N = 25)

	Mean	SD	Range
Age (yr)	43.16	11.96	20-64
Height (cm)	164.99	52.46	154.93-185.59
Weight (kg)	83.70	16.94	70.0-123.0
WHR	.91	.04	.85-.98
Body Fat (HW)	42.84	7.99	29.75-68.50

Comparison of Methods

One of the major focuses of the paper was to compare the accuracy of BIA to HW.

Hypothesis One

Hypothesis one stated that there would be no significant differences in body fat of obese females when measured by BIA and HW. Paired t-tests and Pearson product-moment correlations were used to compare body fat and FFM as determined by BIA and HW. Table 2 presents the results of the analysis.

Table 2. Comparison of Body Fat and FFM as Determined by BIA to HW

	BIA	HW	r	Diff(%)
Body Fat(%)	33.92 ± 6.39	42.84 ± 6.30	.59	-8.92(20)*
FFM (kg)	54.79 ± 6.89	44.08 ± 6.80	.63	10.7(24)*

* Indicates Significant Difference Between Methods p<.05

The results showed that all 25 participants had BIA values below the HW values, with the means being significantly ($p<.05$) different from each other. The correlation between the two methods was $r = .59$. Hypothesis one was rejected.

Hypothesis Two

Hypothesis two stated that a prediction equation could be developed to accurately predict body composition using the BES 200Z BIA. Multiple regression analysis was used to develop several regression equations for prediction of body composition using the BES 200Z BIA. The equations used the variables height^2, weight, age, R, WHR, and ht^2/R, and predicted either FFM or percent body fat. Table 3 presents the eight prediction equations that were developed from the data in this study, along with the correlation coefficients and standard error of the estimate (SEE) for each equation.

Table 3. Prediction Equations Developed to Predict FFM and Body Fat (%)

FFM

1. $FFM = 83.92938 - .04275\ (age) + .00043\ (ht^2) + .49633\ (wt) - .00052\ (R) - 96.72187\ (WHR)$ $(r = .97;\ SEE = 2.29)$

2. $FFM = 95.11549 - .03942\ (age) + .49696\ (wt) + .09118\ (ht^2/R) - 102.18383\ (WHR)$ $(r = .96;\ SEE = 2.44)$

3. $FFM = 7.37932 - .16918\ (age) + .00065\ (ht^2) + .34317\ (wt) + .00163\ (R)$ $(r = .91;\ SEE = 3.62)$

4. $FFM = 19.34258 - .17301\ (age) + .31900\ (wt) + .15637\ (ht^2/R)$ $(r = .89;\ SEE = 3.82)$

Body Fat

1. $Body\ Fat = 125.07\ (WHR) + .07595\ (age) - .00039\ (ht^2) + .04624\ (wt) - .00026\ (R) - 67.22633$ $(r = .91;\ SEE = 2.88)$

2. $Body\ Fat = 130.11444\ (WHR) + .07252\ (age) + .04663\ (wt) - .08029\ (ht^2/R) - 77.84045$ $(r = .90;\ SEE = 2.94)$

3. $Body\ Fat = 31.76350 + .23944\ (age) - .00067\ (ht^2) + .24435\ (wt) - .00305\ (R)$ $(r = .74;\ SEE = 4.63)$

4. $Body\ Fat = 18.64399 + .24262\ (age) + .27323\ (wt) - .16329\ (ht^2/R)$ $(r = .71;\ SEE = 4.76)$

Each of the prediction equations developed used the variables weight and age. The eight prediction equations did have three qualities that could differentiate them from each other. The first characteristic was that the equation either predicted FFM or percent body fat. The equations predicting FFM had higher correlations to HW ($r = .89$ to $.97$) than those predicting percent body fat ($r = .71$ to $.91$). The second characteristic of the eight prediction equations was using the ht^2/R as a single variable or $height^2$ and R separately. Those equations using the variables $height^2$ and R had a slightly higher correlation to HW ($r = .74$ to $.97$) than ht^2/R ($r = .71$ to $.96$). The last characteristic was the inclusion of the WHR variable. The equations that used this variable had a higher correlation to HW ($r = .90$ to $.97$) than the equations that did not use the variable ($r = .74$ to $.91$). The best prediction equation developed from this study used the variables $height^2$, R, WHR, weight, age, and predicted the FFM. Hypothesis two was accepted, since an accurate prediction equation was developed.

Summary of the Results

Body composition via BIA was significantly underpredicted in all 25 participants. This indicates that the prediction equation for the BES 200Z needs to be modified to be a more accurate tool for assessing body composition in obese women. Various prediction equations were developed from the data collected in this study. The best correlation between the BIA prediction equations developed in this study and HW was $r = .97$. This equation predicted FFM and used the variables $height^2$, R, WHR, weight, and age. The following sections discusses the prediction equations for determining FFM and percent fat using the BES 200Z BIA.

Discussion

This section discusses the significance of the findings in relation to published research.

Bioelectrical Impedance Versus Hydrostatic Weighing

Many authors have proposed that BIA is a highly accurate method to determine body composition when compared to HW (Guo et al., 1987; Lukaski et al., 1986, Lukaski, 1987). The results of this study show that the BES 200Z BIA significantly underpredicted body fat in women with greater than 30% body fat. This is consistent with the findings of other authors (Eston et al., 1989; Segal et al., 1985). Cohn (1985) argues that the principle of BIA is that the body has a uniform and inherent distribution of body fluids. This may not be the case in all individuals.

The other factor in this study is the instrument used. The RJL-Systems is the machine that is frequently used for research purposes, and as such, many accurate prediction equations have been developed for this instrument. The BES 200Z has only the prediction equation developed from the manufacturer, which is a generalized prediction equation used for all populations. Thus, it seemed important to develop a specific prediction equation for obese women using the BES 200Z BIA.

Prediction Equations for Bioelectrical Impedance Analysis

Traditionally, prediction equations for BIA use ht^2/R to predict body fat. This was thought to be the best predictor of body composition (Guo et al., 1987, 1989; Khaled et al., 1988; Lukaski et al., 1986). However, Gray et al. (1989) and Segal et al. (1988) used $height^2$ and R as two separate variables and found very high correlations between the BIA equations for the RJL-Systems machine and HW. The results from this study showed slightly better correlations when using height^2 and R separately as compared to using ht^2/R.

The prediction equations developed in this study were for FFM and for percent fat. The prediction equations for FFM had higher correlations to HW than did the equations for percent fat. Most prediction equations predict FFM (Khaled et al., 1988; Lukaski et al., 1986; Segal et al., 1988).

The best prediction equation developed from this study predicted FFM and used the variables height^2, R, weight, WHR, and age. When the WHR was incorporated into the prediction equation the highest correlation coefficient ($r = .97$) was obtained. This correlation was higher than the ones reported in the literature using the RJL-Systems BIA machines on obese subjects. Segal et al. (1988) reported a correlation coefficient of $r = .95$. Gray et al. (1989) reported a correlation of $r = .92$ for women 31-48% fat and $r = .96$ for women greater than 48% fat. Both studies used the variables of height^2, R, weight, and age.

Gray et al. (1990) concluded that skinfold measurements tend to underestimate total body fatness and that would not be a good assessment tool to use by itself. However, anthropometric measurements have been added to BIA prediction equations to increase their accuracy. Little et al. (1990) used the sum of four skinfolds (tricep, scapula, abdomen, and calf) in addition to the variables height^2, R, and age for the prediction equation. The addition of skinfolds was found to increase the accuracy of the prediction equation by 3% and improved the correlation coefficient from $r = .86$ to $r = .89$. Chumela, Baumgartner, and Roche (1988b) suggested the possibility that prediction equations using R could be improved with the addition of other anthropometric measurements. This can be accomplished by adding a measure of fat distribution such as the WHR. The authors stated that whole body impedance may be relatively insensitive to changes in intra-abdominal fat. Bioelectrical impedance analysis may also underestimate total body fatness in the presence of increasing intra-abdominal fat because the greatest proportion of body resistance is accounted for in the arm and leg with a smaller fraction in the trunk. Thus, for obese people, the WHR variable may increase the reliability of BIA prediction equations. This study found that it did improve the correlation between BIA and HW.

Summary

This project was designed to examine the validity of the BES 200Z BIA compared to HW in women whose body fat was greater than 30%. The results showed that the BIA method significantly underpredicted body fat in this population.

This project was also designed to develop prediction equations for women with greater than 30% body fat when analyzed using the BES 200Z impedance instrument. The best prediction equation developed was highly correlated with HW ($r = .97$). The equation predicted FFM and used the variables height^2, R, weight, WHR, and age. The variables that increased the correlation of the prediction equation to HW were WHR and height^2 and R as two separate variables. Also, the equation predicted FFM. These variable significantly increased the prediction of body fat.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine body composition in women with greater than 30% body fat and to develop a prediction equation for the BES 200Z BIA specific for this sample.

Thirty women enrolled in a community weight loss class in La Crosse volunteered to have their body composition assessed. Each subject's body composition was determined by BIA and HW. A total of 25 women completed the testing procedures.

The results showed that all the BIA values underpredicted body fatness. This value was significantly different than the HW value ($p<.05$). Prediction equations for body fat and FFM were then developed which used the following variables: height^2, R, weight, age, WHR, and ht^2/R. The highest correlated prediction equation used the variables ht^2/R, weight, age, and WHR. This equation predicted FFM.

Conclusions

This study showed that the manufacturer's prediction equation used with the BES 200Z BIA underpredicts body fat in women with values of greater than 30%. To increase the correlation between BIA and HW, new prediction equation needed to be developed. The correlation between the manufacturer's prediction equation and HW was $r = .59$. The best equation developed from this study had a correlation of $r = .97$. The variables used for that prediction equation were height^2, R, age, weight, and WHR. One factor that increased the correlation between HW and BIA was the use of the WHR.

Other methods exist to determine body composition. Hydrostatic weighing, which was used in this study, is highly accurate but not a practical assessment tool for women with greater than 30% body fat. The women in this study found it difficult to perform the HW test. Skinfold measurements are also used to determine body composition. Gray et al. (1989) concluded that skinfold measurements would tend to underestimate total body fatness. Skinfold measurements have been used in conjunction with BIA prediction equation to increase the accuracy of the equation ($r = .89$). However, a better anthropometric tool used in conjunction with a BIA equation for women greater than 30% body fat is the WHR. Chumela et al. (1988b) found that BIA may underestimate total body fatness in the presence of increasing intra-abdominal fat because the greatest proportion of body resistance is accounted for in the arms and legs with a smaller fraction in the trunk. This study found a high correlation between the new prediction equation and HW. Also, BIA is a non- invasive, non-threatening instrument used on obese subjects. Thus, BIA with a highly correlated prediction equation to HW would be a good assessment tool to use for women greater than 30% body fat.

Recommendations for Future Research

Based upon the findings of this study, the author recommends the following for future research:

1. This study used 25 participants for the sample size. A larger sample size with more representation from each age group would be more appropriate.
2. Height was a variable in the prediction equation. Three of the 25 women were taller than 178 cm. These three women had a large range between the body fat predicted from HW and BIA. A study should be done to determine if the prediction equations developed from this study for body composition of women greater than 178 cm is accurate.
3. A study could be done on men with greater than 20% body fat and a prediction equation could be developed using the same variables as this study. Waist-to-hip ratio could be used to see what effect it would have on predicting body fat for men. Since men and women deposit their fat differently, the WHR variable may not be as significant in the men's prediction equation.
4. The equations developed in this study need to be cross-validated. A prediction equation should always be tested on many subjects of the population that it was developed for and on the instrument being evaluated. Only then can its validity be determined as an appropriate assessment tool.

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APPENDIX A

INFORMED CONSENT DOCUMENT

INFORMED CONSENT AND RELEASE
BODY COMPOSITION DETERMINATION OF WOMEN GREATER THAN 30 PERCENT BODY FAT

PRINCIPLE INVESTIGATOR: Shari Bauer
TELEPHONE NUMBER: 782-0663

PLEASE READ THOROUGHLY BEFORE AGREEING TO PARTICIPATE IN THIS STUDY. YOUR INFORMED CONSENT AND RELEASE, AS EVIDENCED BY YOUR SIGNATURE BELOW, MUST BE OBTAINED PRIOR TO HAVING ANY TEST ADMINISTERED.

I, ______________________, volunteer to have my body composition determined via underwater weighing and bioelectrical impedance analysis. The purpose of determining my body composition is to assess my percent of lean tissue and body fat. The importance of assessing a person's body fat is that excessive amounts are associated with a variety of health related problems.

PROCEDURES

The following procedures will be used to determine your body composition. The first thing you will do is review and sign the informed consent if you decide to participate in the study. After that you will be asked to complete a medical history questionnaire. Once this is completed, you will put on your swimsuit and have your height, weight, and waist measurements taken. Then you will lie down on a table to have your body composition determined by bioelectrical impedance. Four electrodes will be attached to your body and a small electrical current will be sent through your body. You will not feel any pain. The electrodes will be removed and you will be asked to shower. You must get your entire body wet from head to toe. Once this is done, you will step into the hydrostatic weighing tank and have your residual volume and body composition determined via hydrostatic weighing. A complete report of the results from the testing will be explained to you before leaving the lab. The details of the procedures performed today are listed below.

BIOELECTRICAL IMPEDANCE: Four electrodes will be placed on your body. Two on the hand region and two on the foot. An electrical current will be sent through your body but you will not feel it. Your body's resistance to this small electrical current will be determined and used to calculate body fat.

RESIDUAL VOLUME: This procedure is used to determine the amount of air left in your lung after a forced expiration. A clip will be placed on your nose and you will breath from a bag filled with oxygen. After you have adjusted to this, your will breathe in deeply and then expire all the air in your lungs. Keeping your mouth on the cylinder mouth piece deep breathing is continued until the tester tells you to stop.

HYDROSTATIC WEIGHING: This procedure will be done in the hydrostatic weighing tank with the body submerged up to the shoulders. You will be asked to blow out all of the air in your lungs and bring your body forward submerging your body and head in the water while remaining seated on the chair. When all your air is blown out, signal the tester by raising your finger. Hold as still as possible for five seconds. The tester will instruct you to come up out of the water.

DISCOMFORT OR RISKS

A discomfort with the residual volumes is that a maximal exhalation of air is required and you may experience some light headedness. Another discomfort may be the nose clip that you are instructed to place on your nose when determining residual volume. A risk or discomfort with hydrostatic weighing is that you are required to blow out all air and remain still for a couple of seconds under the water which may cause some fear. The bioelectrical impedance machine sends a small electrical current through the body but the voltage is small and does not cause adverse effects.

BENEFITS

The benefit of the testing today is that you will know your percent fat. This will help you evaluate your risk for unhealthy diseases in the future.

WITHDRAWAL

I have the opportunity to withdraw from testing at any time without prejudice.

QUESTIONS

I have the ability to ask questions at any time about the procedures and results of the testing. If you have questions at any time call the principal investigator at the listed number above.

CONFIDENTIALITY

All of the results from the testing will be kept confidential, but may be used for research purposes in an anonymous form.

The purpose and the procedures of this research project have been explained. I have been told about, and understand, all the predictable discomforts, risks, and benefits that might result. Nevertheless, I agree to participate as a subject in this research project.

I, the undersigned, release and hold harmless and free from all liability associated with these services the test administers and the University of Wisconsin-La Crosse together with all of its agents.

Your Signature ____________________ Date ____________

Witness ____________________ Date ____________

APPENDIX B

MEDICAL HISTORY QUESTIONNAIRE

MEDICAL HISTORY QUESTIONNAIRE

PLEASE NOTE: All the information you provide will be kept **CONFIDENTIAL**

Name: ____________________ Sex: ____________________
Date of Birth: ____________________ Today's Date: ____________________

DIET

1. Height: ____________________ Weight: ____________________
   Elbow Breadth/Frame Size: ____________________
2. How long have you been at your current weight? ____________________
3. Does your physician want you to lose weight? ____________________
4. Are you currently following a diet prescribed by your physician or dietitian? _____ Yes _____ No If yes, what type of diet?
   _____ Weight Reduction _____ Salt Restricted _____ Diabetic
   _____ Low-fat, Low-cholesterol _____ Other (specify) ____________
5. How much water do you drink per day? _____ (glasses/day)
6. Do you drink coffee? _____ Yes _____ No
   If yes, how many cups (8 oz) per day? _____
7. Do you drink diet soda? _____ Yes _____ No
   If yes, how many cups (8 oz) per day? _____
8. Do you drink tea? _____ Yes _____ No
   If yes, how many cups (8 oz) per day? _____
9. Are you taking diuretics? _____ Yes _____ No
10. Are you near menses (within 4 days)? _____ Yes _____ No
11. Have you exercised in the past 24 hours? _____ Yes _____ No
12. Have you eaten in the past 4 hours? _____ Yes _____ No
13. Have you drank any products that were caffeinated today?
    _____ Yes _____ No
14. Have you drank at least one glass of water today?
    _____ Yes _____ No

EXERCISE ASSESSMENT

1. How many days per week do you participate in some type of exercise session that lasts at least 20 minutes? ____________________
2. What type of exercise do you participate in? ________________

MEDICAL ASSESSMENT

1. Please circle any of the following health problems you presently have. (Circle all that apply)

Blood Total Cholesterol at or above 200 mg/dl
HDL-Cholesterol Level below 35 mg/dl
Elevated Triglyceride Levels above 250 mg/dl

Heart Attack or Heart Disease
Peripheral Vascular Disease
Abnormal Electrocardiogram
Disease of the Arteries
Chronic Lower Back Pain
Gallbladder/Gallstones
High Blood Pressure
Diabetes Mellitus

Rheumatic Fever
Kidney Stones
Being a Male
Constipation
Strokes
Ulcers
Anemia
Smoking (Cigarette)

Family History of Heart Disease (< 55 years of age)

2. Do you ever experience any of the following? (Circle all that apply)

Heart Palpitations
Chest Pain
Dizziness or Fainting Spells

Chronic Stomach Pain
Joint Pain
Shortness of Breath

3. Please list any personal medical problems? ____________________
4. Please list any current medications you are taking? ____________
____

APPENDIX C

RAW DATA

RAW DATA

AGE	HT	HT^2	WT	WHR	IMPEDANCE	FFM
24	171.5	29395.10	70.10	.85	502	48.23
35	162.5	26425.75	71.44	.86	523	46.91
57	171.4	29395.10	72.31	.89	640	42.37
38	165.1	27258.01	76.62	.91	607	45.73
31	154.9	24006.40	75.91	.85	486	45.62
40	165.1	27258.01	122.73	.93	409	61.6
57	160.0	25606.42	69.8	.87	589	42.44
47	160.0	25606.42	91.4	.94	527	50.73
49	162.5	26425.75	78.4	.90	489	46.73
35	157.4	24799.95	94.8	.94	483	46.26
23	154.9	24006.40	71.4	.86	458	46.05
54	165.1	27258.01	60.5	.87	593	36.24
48	162.5	26425.75	93.2	.98	448	44.36
41	165.1	27258.01	123.0	.96	386	61.87
20	182.8	33445.09	101.8	.94	497	57.21
41	181.6	32982.19	113.6	.89	445	68.50
41	172.7	29832.19	79.5	.91	445	43.49
47	170.1	28961.23	87.7	.91	488	47.36
62	149.8	22458.02	70.5	.96	494	29.75
35	160.0	25606.40	70.9	.88	477	45.31
56	179.0	32066.07	89.8	.94	464	48.58
48	165.1	27258.01	87.7	.94	464	45.43
64	161.2	26014.46	79.5	.93	427	45.79
52	158.7	25201.56	73.2	.89	499	44.43
30	160.0	25606.40	66.8	.86	516	42.28

HW Values	BIA Values
31.1	22.4
34.3	30.5
41.4	36.4
40.3	40.2
39.9	35
49.8	44
39.2	37.8
44.5	44.3
40.4	32.5
51.2	44.3
35.5	28.9
40.1	27.2
52.4	36.1
49.7	41.2
43.8	34.2
39.7	34.7
45.3	21.5
46.0	33.5
57.8	35.3
36.1	27.9
45.9	26.5
48.2	33.6
42.4	26.9
39.3	31.9
56.7	28.8