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Analysis of body composition with use of body impedance analysis and skinfold calipers: A correlation study

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ANALYSIS OF BODY COMPOSITION WITH USE OF BODY IMPEDANCE ANALYSES AND SKINFOLD CALIPERS: A CORRELATION STUDY

BIVER

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ANALYSIS OF BODY COMPOSITION WITH USE OF BODY IMPEDANCE

ANALYSES AND SKINFOLD CALIPERS: A CORRELATION STUDY

(TITLE)

BY

Deborah J. Biver

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ABSTRACT

ANALYSIS OF BODY COMPOSITION WITH USE OF BODY IMPEDANCE ANALYSES AND SKINFOLD CALIPERS: A CORRELATION STUDY

BY DEBORAH J. BIVER

The purpose of this experiment was twofold; 1) to assess the test-retest reliability of the body impedance analyzer and the skinfold caliper methods of determining percent body fat and, 2) to determine the relationship between the two methods. Percent body fat was determined by skinfold caliper technique and by body impedance analysis on ten male and seven female subjects. Each subject was tested and retested with both methods. Test-retest analysis was evaluated on each measuring procedure and the correlation between the two methods was also assessed. The skinfold caliper technique had a test-retest score of .998 and the BIA technique had a test-retest score of .965. The correlation between the skinfold method and the BIA produced an r value of .859. The results of this study indicated both techniques to have high reliability and high correlation.

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CHAPTER 1

INTRODUCTION

With heart disease being the number one killer in the United States, there is increasing interest in its causes and risk factors. Obesity is known to be one of the risk factors but measuring it by body weight alone has become an obsolete practice. Many researchers believe that the measurement of percent body fat is a more accurate descriptor of obesity. The question and controversy now lies in the means for obtaining this measure.

Measurement of ideal body weight and body composition has been of interest to researchers in the areas of exercise physiology (55, 114), animal science (35, 56), nutrition (3, 10, 38), and growth and development (4). The simplist form of estimating ideal body weight has been to relate it to height (3, 12, 37, 65, 87, 90, 95, 97). Concern over the use of some form of the height/weight ratio as an index of body fat has been expressed by several investigators because of the low correlation of this ratio with body fat (11, 39, 40, 61, 78, 88, 91). In order to obtain a more valid method for the determination of ideal body weight various indirect laboratory methods for the estimation of body density, such as hydrostatic weighing (7, 113), anthropometric measurement (55, 68), measurement of fat-soluable gases (6, 62, 63, 64),

estimation of lean tissue mass by creatinine (42, 46) and 3-methylhistidine excretion (75), and measurement of total body potassium (18, 19, 24, 25), have been established from which body fat can be estimated. Direct methods, which are the only true measures of body fat, include chemical analysis of animal carcasses (53, 76, 79, 80) and human cadavers (22, 36, 73, 77, 82, 102, 109).

Utilizing body density to estimate body composition originated in the 1930's when the United States Navy became interested in developing a practical method for assessment of body fat in divers (9). The hydrostatic weighing procedure that was developed has become the standard against which all other methods of body composition assessment are validated (89, 114). Many variables, including cost factors, availability of space/equipment and knowledge of the technique, preclude the use of hydrostatic weighing in the clinical setting. Therefore other methods such as anthropometrics/skinfold measures have taken prevalance in the clincs when assessing percent body fat.

In recent years the use of body impedance analyzers has been introduced as another simple yet reliable method for determining body fat percentages. A significant amount of research has been conducted on the reliability of the various techniques of estimating percent body fat, and the validation of these techniques against hydrostatic weighing. The correlation between BIA and the skinfold technique has not been thoroughly investigated. The techniques of estimating

percent body fat via the skinfold measurement and BIA are more widely used in the clinic than hydrostatic weighing. For this reason more studies correlating these two techniques to one another appear warrented.

Statement of the Problem

The purpose of this experiment was twofold; 1) to assess the test-retest reliability of the body impedance analyzer and the skinfold caliper methods of determining percent body fat and, 2) to determine the relationship between the two methods.

Hypothesis

The skinfold method and the body impedence analyzer method are both reliable methods for the determination of body composition. Also the body impedance analyzer method of measuring percent body fat correlates highly with the skin fold caliper method.

Limitations

Only male and female participants in the cardiac rehabilitation program at Memorial Hospital in Belleville, Illinois were considered as subjects. Their ages ranged from 48 to 75 years. Another limitation was the instrumentation (BIA) and its preset computations used in the calculation of the final measurements.

Definition of Terms

To promote a better understanding the investigator felt the following terms should be defined:

Body Impedance Analyzer (BIA)

The body impedance analyzer is an instrument used to determine percent body fat from the principle of electrical potentials of the bodily tissue.

Anthropometry

The science that deals with the measurement of girths, depths, widths, sizes, weight, and proportions of the human body.

Hydrostatic Weighing

A procedure done in which body volume is determined by the difference between body weight in air and the weight measured during submersion under water.

Skinfold Caliper

An instrument used to measuure the thickness of skinfolds which are then used to determine percent body fat.

Impedance

A measure of the net hindrance to the flow of an electric current.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The determination of body composition is an area that has received a great deal of attention in the research literature. Utilizing body density to estimate body composition originated in the 1930's when the United States Navy became interested in developing a practical method for assessing body fat in divers. This method of hydrostatic weighing has become the gold standard against which all other methods are typically validated (89, 114). Total body fat per se is not measured directly by any of our convenient laboratory methods, but rather, is predicted from body density measured by a variety of indirect methods (55, 89). The focus of this literature review will be on the use of hydrostatic weighing to measure body density, and the validation of skinfolds and body impedance analysis with hydrostatic weighing. Extensive focus is placed on hydrostatic weighing since it is considered the gold standard. However, once a method achieves the label of gold standard, its limitations are quickly forgotten. The final section of the chapter will focus on the conversion of body density to percent body fat.

Hydrostatic Weighing

The objective of the hydrostatic weighing procedure is to determine body volume which can then be utilized, along with the body weight, to determine body density. Body volume can be determined from the difference in underwater weight and weight in air because the loss of weight of an object in water is equal to the weight of the volume of water it displaces. Therefore, body volume can be calculated from the following equation:

$$BV = (Ma - Mw / Dw) - (LV + 0.1)$$

Where: BV = body volume
Ma = mass of the body in air
Mw = mass of the body in water
Dw = density of water
LV = volume of air in lungs at time of underwater weighing

Once the determination of body volume has been made body density can be easily calculated from the formula; density = mass/volume.

Errors in the determination of body volume from hydrostatic weighing have generally been placed in two categories, biological and technical (55, 66). Biological errors are those that are attributed to biological variation within the subject (i.e., difference in state of hydration). Technical errors are those attributed to the process of the measurement itself. This review will generally address errors that fall into the latter category.

Technical errors in the measurement of body volume by hydrostatic weighing basically fall into two categories, 1) errors in the measurement of lung volume at the time the underwater weight is measured, and 2) errors in the determination of underwater weight.

The air contained in the lungs and the abdominal viscera at the time of underwater weighing contribute to the buoyancy of the body and must be subtracted from the total volume measurement to obtain body volume. The contribution of the gas in the abdominal viscera is small and relatively insignificant, approximately 0.1 liters. The volume of air contained in the lungs; however, is rather large and can cause significant error in the determination if not measured properly (7, 66). Investigations have shown that a 200 ml. error in the measurement of lung volumes could result in a body density error of 0.003 g/ml to 0.004 g/ml (7, 81, 92).

Since hydrostatic pressure during submersion affects lung mechanics in such a way that lung volumes are significantly altered, considerable investigation has been undertaken in an attempt to determine whether lung volumes should be measured with the subject on land or while submerged in water. Investigations using gas dilution techniques have shown mean residual volume (RV) to decrease (1, 13, 52, 81, 86, 92), remain constant (2, 15, 27, 29, 34, 84, 101), or increase (14, 41) when the subject was submerged in water. A closer examination of the individual data indicated that the effect of hydrostatic pressure on RV

was different among subjects within the same study.

It has been demonstated that hydrostatic pressure causes pulmonary air trapping at residual lung volumes smaller than 38 percent of vital capacity measured with the subject submerged to the neck in water,(VCW),(29); therefore, hydrostatic pressure affects large RV differently than small RV. Also, the suspected trapping could lead to erroneous results in the measurement of individual RV during submersion in water. Robertson, et. al. (86), measured RV by plethysmography, which has been shown to be sensitive to pulmonary air trapping, and found that the mean RV values were not different between land and water. However, the individual data indicated that RV decreased (4 subjects), remained constant (3 subjects), or increased (2 subjects) with submersion in water. The data of Robertson, et. al. (86) suggested that the effect of hydrostatic presure on RV depends on the individual. Lohman (66) stated that the measurement of RV on land and while submersed in water produce errors in body density determination of similar magnitude. It therefore, appears that the measurement of RV on land just prior to the hydrostatic weighing procedure is sufficient for the determination of RV during water submersion.

Another important aspect of the hydrostatic weighing process is the ability of the subject to attain the measured RV at the time the underwater weight measurement is made.

The question frequently asked is, how many trials are necessary to acquire a true measure. Katch (54), described two commonly used used methods of RV assessment during hydrostatic weighing, 1) recording the highest value of two to five determinations, and 2) recording the average value of several trials after the time when RV had appeared to stabilize. In this study, the mean values of the underwater weight increased during successive trials of the weighing procedure. It is believed that as an individual becomes accustomed to breathing underwater, they are able to expel more air and thereby increasing their weight underwater (54). Katch (54) concluded that the eigth, ninth, and tenth trials should be used to attain a true underwater weight. Other studies have also shown that an average score rather than the best score is more representative of the true underwater weight (45).

Residual volume has been the lung volume used most widely during hydrostatic weighing because it is the volume least affected by hydrostatic pressure (107). Residual volume is probably the most consistent lung volume to measure both in and out of water, however, the subjects ability to maintain RV accurately or consistently during the period required for the investigator to determine underwater weight has been questioned (103, 104, 107, 108). Attempts have been made to determine body density at lung volumes other than RV. Welch and Crisp (107) reported that body density determined at 50 percent of vital capacity was more comfortable for the

subjects, but the measurement was greater than body density determined at RV. Thomas and Etheridge (103) found body density measured at functional residual capacity (FRC) correlated highly to that measured at RV when FRC was measured with the subject submerged in water. Weltman and Katch (108) found body density measured at total lung capacity (TLC) to be greater than that measured at RV when measurement of TLC was made with the subject out of water. The authors concluded that the two measurements were essentially the same.

Research has shown that TLC is reduced by 1-13 percent when the subject is submerged to the neck in water (13, 34, 41, 86). The error in body density measurement produced by the reduction in TLC is directly related to the weight of the subject in air and inversely related to the percent reduction in TLC. A six percent reduction in TLC for a 70-kg man, with a land measured TLC of six liters, would result in a body density error of 0.0056 g/ml and a percent fat error of two and one half percent. It would appear, therefore, that TLC must be measured in water in order to reduce the error associated with lung volume measuremennt in the determination of body density by hydrostatic weighing at TLC. Timson and Coffman (104) measured body density by hydrostatic weighing at RV and TLC measured on land and TLC with the subject submerged to the neck in water. The data from this study indicated that body density measured at RV and TLC

measured in water were similar but that when TLC was measured on land body density was underestimated.

The studies of Thomas and Etheridge (103) and Timson and Coffman (104) indicate that measurement of body density can be accurately made at lung volumes other that RV if determination of the lung volume is made with the subject in water. This is important to note because many investigators (59, 103, 104, 108) have reported great difficulty in having subjects completely expire all the air in their lungs (i.e., attain RV) while submerged in water. This problem no doubt leads to a significant error in the estimation of body density.

The estimation of RV from vital capacity has been utilized for the determination of body density. The results of the study of Wilmore (111) indicate that while this procedure is fairly accurate there is substantial individual variance and therefore, this method should not be used for research purposes. This position was later supported by Latin and Ruhling (59).

Another source of technical error in the determination of body volume by hydrostatic weighing is the determination of the weight of the individual while submerged in water. Any movement of the water may result in significant oscillation of the scale needle and reduce the ability of the investigator to accurately determine underwater weight. Measurement of underwater weight at lung volumes other than RV greatly reduce this problem (103, 104).

Various points of technical/biological errors of hydrostatic weighing have been discussed. Based on this literature review it is apparent that there are many possible sources of error in the hydrostatic weighing method for the determination of body density. However, at present it remains our most effective indirect means of estimating percent body fat. All other methods are validated against this method.

Skinfold Caliper Method

The method of predicting body density utilizing skin fold calipers was developed as a more simplistic and convenient means of measurement, as opposed to hydrostatic weighing. Ease of application/measurement is an important characteristic, however, in our world of scientific research we need to also establish the reliability and validity of the measuring technique.

Skinfold analysis measures the thickness of a double fold of skin and compressed adipose tissue. The prediction of body density from skinfold measurements assumes that the thickness of a compressed double layer of skin and adiopse tissue is representative of the uncompressed double layer of adipose tissue. This measurement should be indicative of total subcutaneous adiposity. Adiposity must be converted to fat and finally the internal fat must be accounted for (22, 73).

Clarys (22) compared percent body fat from skinfold measurements with actual measured body fat, dissected from six male and seven female cadavers. Results from this study indicated: 1) the mean compressability of various samples ranged from 16 percent to 51 percent, with the variability being attributed to sex, age, site, and level of tissue hydration; 2) two identical skinfold values may mean a large difference in actual adipose tissue thickness; 3) the contribution of skin to total skinfold thickness is generally not large, but it may lead to significant error, especially in lean subjects; and 4) the prediction of subcutaneous fat mass requires some assuumption concerning the fat content of adipose tissue, which increases with increasing adiposity.

More than 100 equations have been developed for utilizing skinfolds in the estimation of body density (66). Many formulas have been developed for specific populations and will not be considered in this review. The remainder of this section will consider equations that have been developed to account for a more general population (i.e., consideration of age, sex, selected skinfold sites).

Jackson and Pollock (48) studied 403 adult men between the ages of 18 and 61 years. Skinfold thicknesses, body circumferences and body density were determined. Multiple regression equations were applied to determine body density from skinfold thickness in combination with age, waist and forearm circumference. The following equation was determined to have the largest r value (r=.918) when correlated with

values determined from hydrostatic weighing. This equation was later cross-validated by Sinning et al., (98).

Body Density= 1.0990750- 0.00008209(X1)+ 0.0000026(X1)2- 0.0002017(X2)-

0.005675(X3)+0.018586(X4)

X1=sum of three skinfold

X2=age in years

X3=waist circumference

X4=forearm circumference

A similar study involving 331 adult women between the ages 18 and 55 years was carried out by Jackson et. al. (50). Body density determined via hydrostatic weighing was compared to skinfold measurements. The authors indicated that the sum of the skinfolds correlated more highly with hydrostatic weighing than any of the individual skinfold measurements. The use of gluteal circumference significantly improved the estimation. The following equation was shown to have the highest r value of .86.

Body Density=1.25186-0.03048(logX1)-0.00011(X2)-0.00064(X3)

X1=sum of seven skinfolds

X2=age in years

X3=gluteal circumference

Durnin and Womersley (33) studied 209 males and 272 females aged 16 thru 72 years. Measurements included skinfolds from four sites, circumferences at three sites and body density determined from hydrostatic weighing. Linear

regression equations were formulated to estimate body density from a single skinfold measurement and from the sums of two or more skinfolds. The results indicated correlation coefficients for the sums of two or more skinfolds and body density to vary from -.70 to -.90. They also concluded that there is an increased accuracy with the use of the more complex equations, but that this increase is minimal. Durnin et.al. (32) demonstrated similiar results when comparing skinfold measurements to hydrostatic weighing in young adults and adolescents. Correlation coefficients ranged from -.76 to -.835, with all coefficients found to be significant.

Inter-tester reliability, which is important in clinics and research labs, has been the focus of much review. Various studies have shown high inter-tester reliability, especially with experienced testers (20, 43, 49, 51, 83). Other studies have shown that the test-retest reliability is lessened with the less experienced measurer (17, 69).

Conversion of Body Density to Percent Body Fat

Many methods of indirectly estimating percent body fat must initially determine body density. Body density values are then converted to percent body fat. The Siri equation (99), is generally used: [Body fat = (4.95/body density)-4.5]

The body density conversion to body fat is based on a two-component model of body composition, (i.e. body fat and lean body mass). A basic assumption is that the densities of these components remain relatively constant amoung

individuals, (i.e. fat has a density of .90 g/ml and lean tissue has a density of 1.10 g/ml). It is also assumed that the lean tissue components of bone and muscle are in about the same proportions between different individuals. The body density value is used to compute the percent body fat and therefore error in body density will reflect on the resultant percent body fat calculation.

Densities of .90 g/ml for fat and 1.10 g/ml for lean tissue are average values for young and middle aged adults. The density of lean body mass in blacks is estimated to be significantly greater than whites, i.e. 1.113 g/ml. (93). The existing equation would therefore tend to overestimate the lean body mass in this population. Also young children and older adults have a varying skeletal density, due to childhood growth periods and the demineralization or osteoporosis occuring in adults (114). This variance accounts for an actual density of lean tissue lower than the assumed 1.10 g/ml. As a result lean tissue will be underestimated and percent body fat will be overestimated.

Another example of the variance with body density is with highly trained athletes whose lean tissue density could exceed 1.10 g/ml, which would result in an underestimation of percent body fat and the negative values occassionally reported. Variability in the fat-free body components has not been well defined within many populations, including children, women, athletes, and the elderly (68). A

prediction error of two to four percent can occur when converting body density to percent body fat, dependent upon the specific population under study (5, 66, 67).

From the above, it appears that the standard equations used to estimate relative body fat from whole body density, e.g., those of Siri (99) and Brozek (16) are not appropiate for all segments of the population. Thus, it is important that researchers and clinicians recognize the potential limitations of estimating percent body fat from body density.

Body Impedance Analysis Method

The impedance method of predicting percent body fat is a newly developed technique and is therefore the focus of much research and debate. The measurement of body composition derived from the body impedance analyzer is based in part on total body water (57, 70). Body tissues contain different amounts of water. Adipose tissuue contains between 12-22 percent water, whereas, lean-body mass contains 71-75 percent water (57, 70). Lean body mass includes body cell mass, extra-cellular mass, extra-cellular fluid and the protein matrix of adipose tissue.

The mechanics involved in obtaining the estimated percent body fat utilizing the BIA have been reviewed by many authors (43, 57, 70). The method is based on the fact that lean tissue has a greater electrolyte and water content than does fat. Lean body mass, therefore, allows electric current to flow through it with less resistance than fat mass,(i.e.

lean tissue has greater conductivity). The body impedance analyzer, as the name indicates, measures the impedance the body offers to an applied 50 khz. 800 microamp current. The percent body fat is thus determined by subtracting the estimated percent lean body mass from the body weight. Various studies (26, 43, 44, 57, 71, 94) have also shown that if the length of the conductor is included in the equation, (i.e. $stature^2$/resistance), prediction of percent body fat is significantly improved.

Studies (20, 43, 51, 57, 60, 70, 94) that have tested the reliability of the BIA method have demonstrated very high r values,(i.e..957-.99). The validity of the machine has been evaluated by many researchers. Kushner and Schoeller (57) studied 58 subjects to determine effectiveness of predicting total body water with the body impedance analyzer as compared to the deuterium-dilution technique (D_2O). This technique, which was used as the control method, estimates total body water by a counting method. The subject receives .06 grams D_2O/kg of estimated body water, then the D_2O dilution space is measured by saliva sampling, before and three and four hours after the oral administration of D_2O. The authors concluded high reliabilities with correlation coefficient for males at .96 and .85 for females. Lukaski et.al. (71) conducted a similiar study with 37 males utilizing the deuterium-dilution technique compared to the BIA procedure. The authors demonstrated strong relationships

between bioelectric measurements, fat free mass and total body water.

Jackson et .al. (51) studied 44 females and 24 males comparing BIA and skinfold measures to the estimated percent body fat determined from hydrostatic weighing. Cross validation studies of BIA to hydrostatic weighing produced values of .71 for females and .76 for males. Jackson et.al. (51) did a similar study on 50 males and 82 females with results showing the BIA to be reliable. The cross validation results with hydrostatic weighing again produced r values of .71 for males and .76 for females. An abstract of a study comparing results of the body impedance analyzer to hydrostatic weighing, done by Lawlor et. al. (60) gave similar correlative values of .779 for males and .728 females. Their sample consisted of 283 males and 103 females.

Hodgdon and Fitzgerald (47) examined the validity of the BIA predictions at various levels of fatness. The subject matter consisted of 403 males and 135 females. Correlative studies between hydrostatic weighing and the BIA resulted in r values of .79 for males and .82 for females. The authors concluded that there was a general overestimation of percent body fat for those individuals with percent body fat values in the lower one third range, and a general underestimation of percent body fat for the individuals in the upper one third of the range.

Chumlea et. al. (21) studied the influence of

physiologic variables and oral contraceptives on bioelectric impedance. The sample group consisted of 78 males and 75 females, between the ages of 19 and 29 years. All individuals were tested for effects of diurnal variation and diet, and the females were tested also for effects from timing of their menstrual cycles. Another sample consisting of 29 females age 21 to 38 years, were used to test effects of timing of menstrual cycles and the use of oral contraceptives on body impedance analysis. The results indicated that the time of day had no significant effect on bioelectric resistance, nor did the interval from the previous meal and/or drink, physical activity level, timing of menstrual cycle, or oral contraceptive usage. The absence of regular physical activity in women did have slight effect, with a tendancy towards underpredicting percent body fat.

Studies directly correlating BIA to skinfold technique are lacking in the present literature. Segal et.al. (94) conducted a comparative study of total body conductivity technique and BIA to anthropometric measures. Seventy five subjects were involved in this study. Correlation of skinfold measures to BIA resulted in a r value of .89.

Summary

The purpose of the current investigation was to determine the relationship between skinfold analysis and BIA for the estimation of percent body fat. This chapter has

focused on the validity and reliability of both methods. Research is limited on the correlation between these two methods of estimating body composition. The hydrostatic weighing method of body composition analysis has been discussed in great detail because it is the standard against which all other methods are validated.

CHAPTER 3

METHODOLOGY

The purpose of this research project was to determine the reliability of the BIA and the skinfold caliper method, as well as the relationship between the two methods. The description of the subjects, use of the equipment, and the collection of data are explained in this chapter.

Subjects

Seventeen subjects, ten males and seven females, were utilized in this study. Males ranged in age from 48 to 75 years and females ranged in age from 49 to 65 years. The subjects were all participants in the cardiac rehabilitation program at Memorial Hospital, Belleville, Illinois. The physical characteristics of the subjects are included in Table 1.

Experimental Methods

Prior to testing, the subjects signed a consent form (Appendix A), completed an information sheet (Appendix B,males; and Appendix C, females), and were given verbal pretesting instructions according to the BIA-103

Table 1

Physical Characteristics of the Subjects.

	Weight(kg)	Age (years)	Height (in)
Male (N=10)			
Mean	62.3	70.0	83.7
SD	7.2	3.1	10.8
Female (N=7)			
Mean	56.9	62.3	61.7
SD	6.3	2.5	10.6

manufacturer's recommendations. The subject was not to have eaten for at least four hours, nor consumed alcohol within 24 hours of the test. No exercise was permitted in the 12 hour period prior to testing.

All testing was conducted in the physical therapy department at the hospital, by the same investigator. Each subject underwent skinfold measuurements and body impedance analysis, on two consecutive mornings.

A Lange skinfold caliper was used to obtain the skinfold measurements for all sites on the right side of the body. Skinfold sites measured on the females included: chest, axilla, triceps, subscapular, abdomen, suprailium and thigh. The gluteal circumference was measured on the females as described by Behnke and Wilmore (9). The skinfold sites

measured on the males included the chest, abdomen and thigh. Waist and foreman circumferential measures were also obtained (9).

The Jackson-Pollock equation was used to calculate the body density from the skinfold measurements (48, 50). Body density was converted to percent fat using the Siri equation (99).

The BIA 103 by RJL system was the electrical impedance instrument used in this study. The subject removed his right shoe and sock and positioned himself supine with the right side of his body adjacent to the body composition analyzer. Four electrodes, two detecting electrodes and two signal introducing electrodes were positioned on the subject. The proximal hand electrode was placed at an imaginary line bisecting the radial and ulnar head, while the distal hand electrode was positioned just proximal to the metacarpal joint of the third finger. The proximal foot electrode was placed at an imaginary line bisecting the lateral and medial malleolus of the ankle, while the distal foot electrode was positioned just proximal to the metatarsal joint of the third toe. Subjects were positioned with legs apart to prevent the thighs from touching one another. The age, height, weight, and physical activity level of each subject was typed into the BIA computer. (See assessment chart, Appendix D).

Statistical Analysis

Two sets of measurements from the skinfold caliper method and two sets of measurements from the BIA were obtained for each subject. A test-retest reliability value was computed for both the skinfold technique and the BIA method.

Once the reliability of the two seperate techniques was established, then a correlative study was done between the skinfold and BIA data. All correlative/test-retest analysis was done utilizing the Pearson Product Method.

CHAPTER 4

ANALYSIS OF THE DATA

The purpose of this study was to investigate the reliability of the skinfold method and of the BIA technique, for determining body composition. In addition, a correlation was computed to establish if a relationship exists beween the two methods.

Data Conversion

Skinfold thicknesses are measured in millimeters. These measurements are used in an equation to calculate body density, which is then converted into percent body fat.

The body impedance analyzer measures resistance in ohms. This measurement is then used in a computation to determine percent body fat.

Findings

Test-retest scores of skinfold measurements produced a correlation of .998, showing this proceduure to be highly reliable. Test-retest scores of the BIA measurements produced a correlation of .965, again showing this method to be highly reliable. Because of the high test-retest reliability of the the two trials representing each method,

Table 2

Test-retest reliability of individual methods and the correlation between skinfold and BIA analyses.

	r value
Reliability of Methods:	
Skinfold	.998
BIA	.965
Correlation Between Methods	.859

an average of these trials was then used in the study of the relationship between the methods. Table 2 reports these findings and the .85 correlation between body compositionas measured by the BIA and body composition as measured by the skinfold analysis.

Discussion

The use of skinfold calipers in assessing percent body fat has been demonstrated to have high test-retest reliability, when an experienced person is performing the evaluation (83). The test-retest correlative value, with experienced examiners, ranged from .85-.99. The results obtained from this study, r=.998, indicated an excellent

test-retest reliability.

Studies (20, 43, 51, 57, 60, 70, 94) have indicated results obtained from the BIA to be highly reliable, with r values ranging from .957 to .990. The r value of .965 obtained for test-retest reliability of the BIA method in this study is indicative of an excellent reliability.

Research projects correlating skinfold techniques directly to body impedance analysis are lacking in the literature. One study (94) did analyze the relationship between the skinfold method and BIA. The r value obtained in this study was .86 which is nearly identical to the value of .859 obtained in this study.

Investigations correlating each individual technique to hydrostatic weighing are more prevalant. Studies (32, 47, 48, 51, 83) that attempted to correlate both skinfold analysis and BIA to hydrostatic weighing generally found the skinfold method to be more highly correlated to the hydrostatic weighing values. Skinfold versus hydrostatic weighing revealed correlations ranging from .76 to .918 as compared to a range of .71 to .935 for the body impedance technique.

The skinfold technique is widely accepted and utilized in the clinical setting as a method for estimating percent body fat. However, with the introduction of the BIA to the field of body composition assessment, many clinics are investigating the feasibility of this method. The advantages of the BIA include ease of administration with minimal personnel training required for test administration,

a computerized printout with useful information which can provide positive motivation for the subject, and a decreased time needed to administer the test and accumulate results.

With clinics wanting to begin to utilize this new method of assessing percent body fat, it is necessary to have studies demonstrating the correlative value of the BIA to the previous methods of attaining this value. The results of this study indicate that clinics will be able to utilize the BIA method of body composition assessment with confidence.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the reliability of the skinfold method and the BIA technique, for determining body composition. In addition, a correlation was computed to establish if a relationship exists between the two methods.

Seventeen subjects, ten males and seven females, ranging in age from 48 to 75 years, were selected for this study. All subjects were participants in the cardiac rehabilitation program at Belleville Memorial Hospital.

The testing procedure consisted of measuring skinfold thicknesses and body impedance on each subject at the same time on two consecutive mornings. Percent body fat was calculated from each measurement.

The Pearson Product Moment correlation method was used to determine reliability of both techniques and was also used to determine the relationship between the two techniques.

Conclusions

The correlation coefficients indicate that the skinfold caliper technique and the body impedance analysis have high

test-retest reliability. The correlation coefficient also indicated that there is a strong relationship between these two methods.

Recommendations

The following recommendations are made based on the results from this study, to conduct further correlation studies specifically between the BIA and the skinfold technique, since this is lacking in the literature; and to conduct reliability/validity studies of the BIA on other populations, specifically those with varying hydration levels,(i.e. athletes, patients on diuretics, or other drugs affecting hydration level.

REFERENCES

1. Agostoni, E., Gurtner, G., Torri, G., and Rahn, H. Respiratory mechanics during submersion and negative-pressure breathing. Journal of Applied Physiology, 21:251-258, 1966.

2. Arborelius, M., Balldin, U.I., Lila, B., Lungren, C.E.G. Regional lung function in man during immersion with the head above water. Aerospace Medicine, 43:701-707, 1972.

3. Baecke, J.A., Burema, J. Deurenberg, P. Body fatness relative weight and frame size in young adults. British Journal of Nutrition, 48:1-6, 1982.

4. Baker, P.K., Dalrymple, R.H., Ingle, D.L., and Ricks, C.A. Use of beta-adrenergic agonist to alter muscle and fat deposition in lambs. Journal of Animal Science, 59:1256-1261, 1984.

5. Bakker, H.K., and Struikenkamp, R.S. Biological variability and lean body mass estimates. Human Biology, 49:187-202, 1977.

6. Behnke, A.R., Thomson, R.M., Shaw, L.A. The rate of elimination of dissolved nitrogen in man in relation to the fat and water content of the body. American Journal of Physiology, 114:137, 1935.

7. Behnke, A.R. Physiologic studies pertaining to deep sea diving and aviation, especially in relation to the fat content and composition of the body. Harvey Lectures, 37:198-226, 1942.

8. Behnke, A.R. Feen, B.G. and Welham, W.C. The specific gravity of healthy men. Journal of American Medical Association, 118:495-498, 1942.

9. Behnke, A.R., Wilmore, J.H. Evaluation and Regulation of Body Build and Composition. Prentice-Hall, Inc. 1974.

10. Beneke, W.M., Timson, B.F., and VanderTuig, J.G. Assessment of health risk benefits of weight loss treatments: a review of methodological and pragmatic considerations. Behavorial Assessment 9:349-359, 1987.

11. Benn, R.T. The mathematical properties of weight-for-height indices used as measure of adiposity. British Journal Preventive and Social Medicine, 25:42-50. 1971.

12. Billewicz, W.Z., Kemsley, W.F.F., and Thompson, A.M. Indices of obesity. British Journal Preventive and Social Medicine, 16:183-188, 1962.

13. Bondi, K.R., Young, J.M., Bennett, R.M., and Bradley, M.E. Closing volumes in man immersed to the neck in water. Journal of Applied Physiology, 40:736-740, 1976.

14. Brandon, L.J., Boileau, R.A., and Lohman, T.G. Comparison of two procedures employed in measuring body density in children. Medicine and Science in Sports Exercise, 13:122, 1981.

15. Brozek, J., Henschel, A. and Keys, A. Effect of submersion in water on the volume of residual air in man. Journal of Applied Physiology, 2:240-246, 1949.

16. Brozek, J., Grande, F., Anderson, J.T., and Keys, A. Densitometric analysis of body composition: revision of some quantitative assumptions. Annals of New York Academy of Science, 110:113-140, 1963.

17. Burkinshaw, L., Jones, P.R.M., and Krupowicz, D.W. Observer error in skinfold thickness measurements. Human Biology, 45:273-279, 1973.

18. Burkinshaw, L. Sex-dependent calibration factor of a whole-body radiation counter. International Journal of Applied Radiation and Isotopes 29:387-390, 1978.

19. Burkinshaw, L. Morgan, D.B., Silverton, N.P., Thomas, R.D. Total body nitrogen and its relation to body potassium and fat-free mass in healthy subjects. Clinical Science, 61:457-462, 1981.

20. Chumlea, W.C., Roche, A.F., Ultrasonic and skinfold caliper measures of subcutaneous adipose tissue thickness in elderly men and women. American Journal of Physical Anthropology, 71: 351-357, 1986.

21. Chumlea, W.C., Roche, A.F., et.al. The influence of physiologic variables and oral contraceptives on bioelectric impedance. Human Biology, 59 No 2: 257-269, 1987.

22. Clarys, J.P., Martin, A.D., Drinkwater, D.T. Gross tissue masses in adult humans: data from 25 dissections. Human Biology, 56:459-473, 1984.

23. Cohen, L. & Holliday, M. Statistics for Education. London: Harper & Roe., 1979.

24. Cohn, S.H., Dombrowski, C.S., Pate, H.R. A whole-body counter with an invariant response to radio-nuclide distribution and body size. Physics in Medicine and Biology, 14:645-658, 1969.

25. Cohn, S.H., Dombrowski, C.S. Absolute measurement of whole body potassium by gamma spectroscopy. Journal of Nuclear Medicine, 11:239-246, 1970.

26. Cohn, S.H. How valid are bioelectric impedance measurements in body composition studies? American Journal of Clinical Nutrition, 42:889-890, 1985.

27. Craig, A.B. and Ware, D.E. Effect of immersion in water on vital capacity and residual volume of the lungs. Journal of Applied Physiology, 23:423-425, 1967.

28. Cunningham, J.J. New Approaches to the non-invasive assessmment of body composition: body impedance analysis and total body electrical conductivity, Nutrition International, 3:6-10, 1987.

29. Dahlback, G.O., and Lundgren, C.E.G. Pulmonary air-trapping induced by water immersion. Aerospace Medicine, 43:768-774, 1972.

30. Donnelly,J.E., Brown, T.E., Israel, R.G., Smith-Sintek, S., O'Brian, K.F., and Caslavka, B. Hydrostatic weighing without head submersion: description of a method. Medicine and Science in Sports and Exercise, 20:66-69, 1988.

31. Durnin, J.V.G.A. and Taylor, A. Replicability of measuurements of density of the human body as determined by underwater weighing. Journal of Applied Physiology, 15(1):142-144, 1960

32. Durnin, J.V.G.A., and Rahaman, M.M. The assessment of the amount of fat in the human body from measurements of skinfold thickness. British Journal of Nutrition 21: 681-689, 1967.

33. Durnin, J.V.G.A., and Womersley, J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. British Journal of Nutrition 32: 77-97, 1974.

34. Etheridge, G.L. and Thomas, T.R. The effect of body position and water immersion on lung volumes of women. Medicine and Science in Sports, 10:61, 1978. (Abstract)

35. Ferrell, C.L. and Cornelius, S.G. Estimation of body composition of pigs. Journal of Animal Science, 58:903-912, 1984.

36. Forbes, R.M., Cooper, A.R., and Mitchell, H.H. The composition of the adult human body as determined by chemical analysis. Journal of Biological Chemistry, 203:359-366, 1953.

37. Forbes, G.B., Amirhakimi G.H. Skinfold thickness and body fat in children. Human Biology, 42:401-418, 1970.

38. Forbes, G.B. Lean body mass-body fat interrelationships in humans. Nutrition Reviews, 45:225-231, 1987.

39. Frisancho, A.R., Flegel, P.N. Relative merits of old and new indices of body mass with reference to skinfold thickness. American Journal of Clinical Nutrition, 36:697-699, 1982.

40. Garn, S.M.,and Pesick, S.D. Comparison of the Benn index and other body mass indices in nutritional assessment. American Journal of Clinical Nutrition, 36:573-575, 1982.

41. Girandola, R.N., Wisewell, R.W., Mohler, J.G., Romero, G.T., and Barnes, W.S. Effects of water immersion on lung volumes: implications for body composition analysis. Journal of Applied Physiology, 43:276-279, 1977.

42. Grant, J.P., Custer, P.B. and Thurrlaw, J. Current techniques of nutritional assessment. Surgical Clinics of North America, 61:437-463, 1981.

43. Guo, S., Roche,A.F.,et.al. Body composition predictions from bioelectric impedance. Human Biology, 59 No 2: 221-233, 1987.

44. Helenius, M.Y.T., et.al. Studies of bioelectric resistance in overweight, middle-aged subjects. Human Biology, 59 No 2: 271-279, 1987.

45. Henry, F.M. Reliability, measurement error, and intra-individual difference. Research Quarterly, 30:21-24, 1959.

46. Heymsfield, S.B., Artega, C., McManus, C., Smith, J. Moffitt, S. Measurement of muscle mass in humans:validity of the 24-hour urinary creatine method. American Journal of Clinical Nutrition, 36:478-494, 1983.

47. Hodgon, J.A., Fitzgerald, P.I., Validity of impedance predictions at various levels of fatness. Human Biology, 59 No 2; 281-298, 1987.

48. Jackson, A.S., and Pollock, M.L. Generalized equations for predicting body density of men. British Journal of Nutrition, 40:497-504,1978.

49. Jackson, A.S., Pollock. M.L., and Gettman, L.R. Intertestee reliability of selected skin-fold and circumference measurements and percent fat estimates. Research Quarterly, 49:546-551, 1978.

50. Jackson, A.S., Pollock, M.L., Ward, A. Generalized equations for predicting body density of women. Medicine and Science in Sports and Exercise, 12(3): 175-182, 1980.

51. Jackson,A.S., Pollock, M.L., Graves, J.E., and Mahar, M.T. Reliability and validity of bioelectrical impedance in determining body composition. Journal of Applied Physiology, 64(2): 529-534, 1988.

52. Jarrett, A.S. Effect of immersion on intrapulmonary pressure. Journal of Applied Physiology, 20:1261-1266, 1965.

53. Jones, E.M., Montoye, H.J., Johnson, P.B., Martin, Sr. M.J.M., Van Huss, W.D., and Cederquist, D. Effects of exercise and food restriction on serum cholesterol and liver lipids. American Journal of Physiology, 207:460-466, 1964.

54. Katch, F.I. Apparent body density and variability during underwater weighing. Research Quarterly of Exercise and Sport, 39:993-999, 1968.

55. Katch, F.I., Katch, V.L. Measurement and prediction errors in body composition assessment and the search for the perfect prediction equation. Research Quarterly of Exercise and Sport, 51(1): 249-260, 1980.

56. Kraybill, H.F., Bitter, H.L. and Hankins, O.G. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. Journal of Applied Physiology, 4:575-584, 1952.

57. Kushner, R.F., Schoeller, D.A. Estimation of total body water by bioelectrical impedance. American Journal of Clinical Nutrition, 44:417-424, 1986.

58. Latin, R.W. and Ruhling, R.O. Comparison of hydrostatic weighing at total lung capacity, measured residual volume, and predicted residual volume in older men. Medicine and Science in Sports and Exercise, 15:172-173, 1983.

59. Latin, R.W. and Ruhling, R.O. Total lung capacity, residual volume and predicted residual volume in a densitometric study of older men. British Journal of Sports Medicine, 20:66-68, 1986.

60. Lawlor, M.R., Crisman, R.P., and Hodgdon, J.A. Bioelectrical impedance analysis as a method to assess body composition (Abstract). Medicine and Science in Sports and Exercise, 17:271, 1985.

61. Lee, J., Kolonel, L.N., and Hinds, M.W. Relative merits of the weight-corrected-for-height indices. American Journal of Clinical Nutrition, 34:2521-2529, 1981.

62. Lesser, G.T., Peri, W., and Steele, J.M. Determination of total body fat by absorbtion of an inert gas: measurement and results in normal human subjects. Journal of Clinical Investigation, 39:1791, 1960.

63. Lesser, G.T., and Deutsch, S. Measurement of adipose tissue blood flow and perfusion in man by uptake of krypton. Journal of Applied Physiology, 23:621, 1967.

64. Lesser, G.T., Deutsch, S. and Markofsky, J. Use of independent measurement of body fat to evaluate overweight and underweight. Metabolism, 20:792, 1971.

65. Lohman, T.G., Boileau, R.A., and Massey, B.H. Prediction of lean body mass in young boys from skinfold thickness and body weight. Human Biology, 47:245-262, 1975.

66. Lohman,T.G., Skinfolds and body density and their relation to body fatness: a review. Human Biology, 53:181-225, 1981.

67. Lohman,T.G., Body composition methodology in sports medicine. Physician and Sports Medicine, 10:47-58, 1982.

68. Lohman,T.G., Research progress in validation of laboratory methods of assessing body composition. Medicine and Science in Sports and Exercise, 6:596-603, 1984.

69. Lohman,T.G., Pollock, M.L., Slaughter, M.H., Brandon, L.J., and Boileau, R.A. Methodological factors and the prediction of body fat in female athletes. Medicine and Science in Sports and Exercise, 16(1):92-96, 1984.

70. Lukaski, H.C., Johnson, P.E., Bolonchuk, W.W., and Lykken, G.I. Assessmment of fat-free mass using bioelectrical impedance measurements of the human body. American Journal of Clinical Nutrition, 41:810-817, 1985.

71. Lukaski, H.C., Bolonchuk, W.W., Hall, C.B., and Siders, W.A. Validation of tetrapolar bioelectrical impedance method to assess human body compostion. Journal of Applied Physiology, 60(4):1327-1332, 1986.

72. Marks, C. and Katch, V. Biological and technological variability of residual lung volume and the effect on body fat calcluations. Medicine and Science in Sports and Exercise, 18:485-488, 1986.

73. Martin, A.D., Ross, W.D., Drinkwater, D.T., and Clarys, J.P. Prediction of body fat by skinfold caliper: assumptions and cadaver evidence. International Journal of Obesity, 9,Suppl. 1:31-39,1985

74. McGarty, J.M., Butts, N.K., Hall, L.K., and Fletcher, R.A. Comparison of three hydrostatic wieghing methods. Medicine and Science in Sports and Exercise, 15:181, 1983.

75. Mendez, J., Lukaski, H.C., Buskirk, E.R. Fat-free mass as a function of max. O_2 consumption and 24-hour urinary creatine, and 3-methylhistidine excretion. American Journal of Clinical Nutrition, 39:710-715, 1984.

76. Mickelsen, O. and Anderson, A.A. A method for preparing intact animals for carcass analysis. Journal of Laboratory Clinical Medicine, 53:282-290, 1959.

77. Mitchell, H.H., Hamilton, T.S., Steggerda, F.R., and Bean, H.W. The chemical composition of the adult human body and its bearing on the biochemistry of growth. Journal of Biological Chemistry, 158:625-637, 1945.

78. Norgan, N.G. and Ferro-Luzzi, A. Weight-height indices as estimatiors of fatness in men. Human Nutrition Clinical Nutrition , 36C:363-372, 1982.

79. Oscai, L.B., Spirakis, C.N., Wolff, C.A., and Beck, R.J. Effects of exercise and of food restriction on adipose tissue cellularity. Journal of Lipid Research, 13:588-592, 1972.

80. Oscai, L.B., Babirak, S.P., Dubach, F.B., McGarr, J.A., and Spirakis, C.N. Exercise or food restriction: effect on adipose tissue cellularity. American Journal of Physiology, 227(4): 901-904, 1974.

81. Ostrove, S.M., and Vaccaro, P. Effect of immersion on RV in young women: Implications for measurement of body density. International Journal of Sports Medicine, 3:220-223, 1982.

82. Pawan, G.E.S., and Clode, M. The gross chemical compositiion of subcutaneous adipose tissue in the mean and obese human subject. Journal of Biochemistry, 74:9,1960.

83. Pollock, M.L., Hickman, T., Kendrick, Z., Jackson,A., Linnerud, A.C., Dawson, G. Prediction of body density in young and middle-aged men. Journal of Applied Physiology, 40(3): 300-304, 1976.

84. Prefaut, C., Lupi-h, E., and Annthonisen, N.R. Human lung mechanics during water immersion. Journal of Applied Physiology, 40:320-323, 1976.

85. Presta, E., Wang, J., Harrison G.G., Bjorntorp, P., Harker, W.H., and VanItallie, T.B. Measurement of total body electrical conductivity: a new method for estimation of body composition. American Journal of Clinical Nutrition, 37:735-739, 1983.

86. Robertson, C.H., Engle, C.M., and Bradley, M.E. Lung volumes in man immersed to the neck; dilution and plethysmographic techniques. Journal of Applied Physiology, 44:679-682, 1978.

87. Roche, A.F., Siervogel, R.M., Chumlea, C., and Webb, P. Grading body fatness from limited anthropometric data. American Journal of Clinical Nutrition, 34:2831-2838, 1981.

88. Roche, A.F. Research progress in the field of body composition. Medicine and Science in Sports and Exercise, 16:579-583, 1984a.

89. Roche, A.F., Some aspects of the criterion methods for the meassurement of body composition. Human Biology, 59 No 2:209-220, 1987.

90. Rolland-Cachera, M.F., Sempe, M., Guilloud-Battaille,M., Patoix, E., Pequignot-Guggenbuhl, F., and Fautrad, V. Adiposity indices in children. American Journal of Clinical Nutrition, 36:178-184, 1982.

91. Rosenbaum, S. and Skinner, R.K. A survey of heights and weights of adults in Great Britain, 1980. Annals of Human Biology, 12:115-127, 1985.

92. Sawka, M.N., Weber, H.R., and Knowlton, R.G. The effect of total body submersion on residual lung volume and body density measuurements in man. Ergonomics, 21:89-94, 1978.

93. Schutte, J.E., et al. Density of lean body mass is greater in blacks than whites. Journal of Applied Physiology, 56:1647, 1984.

94. Segal, K.R., Gutin, B., Presta, E., Wang, J., and VanItallie, T.B. Estimation of human body composition by electrical imppedance methods: a comparative stuudy. Journal of Applied Physiology, 58(5):1565-1571, 1985.

95. Seltzer, C.C., Goldman, R.F., and Mayer, J. The triceps skinfold as a predictive measure of body density and body fat in obese adolescent girls. Pediatrics, 36:212-218, 1965.

96. Shaw, V.W. The accuracy of two training methods on skinfold assessment. Research Quarterly in Exercise and Sport, 57:85-90, 1986.

97. Shephard, R.J., Jones, J., Ishii, K., Kaneko, M., and Albrecht, A.F. Factors affecting body density and thicknness of subcutaneous fat: data on 518 Canadian city dwellers. American Journal of Clinical Nutrition, 22:1175-1189, 1969.

98. Sinning, W.E. et. al. Validity of 'generalized' equations for body composition analysis in male athletes. Medicine and Science in Sports and Exercise, 17 No 1: 124-130, 1985.

99. Siri, W.E. Gross composition of the body. In: Advances in Biological and Medical Physics, IV, J.H. Lawrence and C.A. Tobias (Eds.) New York, Academic Press, 1956.

100. Slaughter, M.H., Lohman, T.G., Pollock, A.L., Brandon, J., and Boileau, R.A. Influence of caliper, investigator, and prediction equations on body fat estimates in female college athletes. In: Abstracts: of Research Papers, Virginia: AAHPERD, 1982.

101. Sloan, A.W., and Bredell, G.A.G. A comparison of two simple methods of determining pulmonary residual volume. Human Biology, 45:23-29, 1973.

102. Thomas, L.W. The chemical composition of adipose tissue of man and mice. Quarterly Journal of Experimental Physiology, 47:179-188, 1962.

103. Thomas, T.R. and Etheridge, G.L. Hydrostatic weighing at residual volume and functional residual capacity. Journal of Applied Physiology, 49:157-159, 1980.

104. Timson, B.F. and Coffman, J.L. Body composition by hydrostatic weighing at total lung capacity and residual volume. Medicine and Science in Sports and Exercise, 16:411-414, 1984.

105. Ward, G.M., Kryzwicki, H.J., Rahman, D.P., Quass, R.L., Nelson, R.A. Relationship of anthropometric measurements to body fat as determined by densitometry, potassium-40 and body water. American Journal of Clinical Nutrition, 28:162-169, 1986.

106. Warner, J.G., Yeater, R., Sherwood, L., and Weber, K. A hydrostatic weighing method using total lung capacity and a small tank. British Journal of Sports Medicine, 20:17-21, 1986.

107. Welch, B.E. and Crisp, C.E. Effect of the level of expiration on body densiity measurement. Journal of Applied Physiology, 12:210-213, 1958.

108. Weltman, A. and Katch, V. Comparison of hydrostatic weighing at residual volume and total lung capacity. Medicine and Science in Sports and Exercise, 13:210-213, 1981.

109. Widdowson, E.M., McCance, R.A., and Spray, C.M. The chemical composition of the human body. Clinical Science, 10:113-125, 1951.

110. Williams, D., Anderson, T., and Currier, D. Underwater weighing using the hubbard tank vs the standard tank. Physical Therapy, 64:658-663, 1984.

111. Wilmore, J.H. A simplified method for the determination of residual lung volume. Journal of Applied Physiology, 27:96; 1969.

112. Wilmore, J.H. The use of actual, predicted and constant residual volumes in the assessment of body composition by underwater weighing. Medicine and Science in Sports and Exercise, 1:87-90, 1969.

113. Wilmore, J.H. Appetite and body composition consequent to physical activity. Research Quarterly in Exercise and Sport, 54:415, 1983.

114. Wilmore, J.H. Body composition in sport and exercise: directions for future research. Medicine and Science in Sports & Exercise, 15:21-31, 1983.

APPENDIX A

INFORMED CONSENT

I_____________________________, state that I wish to participate in the research project by Deborah Biver.

The purpose of the research is to investigate the correlation of results obtained from predicting percent body fat from two separate methods; 1) the skinfold caliper technique and 2) the body impedance method. My participation involves approximately 1 hour of time in the Physical Therapy Department at Belleville Memorial Hospital. This hour is divided into two sessions on two consecutive days. While participating in this research I agree to try to keep my activities and eating habits consistant over the testing days. I also agree that prior to the testing I will not have: 1) eaten for four hours, 2) exercised for 12 hours, or 3) had alcohol in 24 hours.

A benefit of this study is to learn my predicted body fat. The personal risks are minimal. I may discontinue participation at any time without questions being asked. All my questions have been answered concerning the study. I consent to the anonymous use of my information in a research project.

I have read the above statement and do understand all the risks and benefits associated with this study. I freely and voluntarily consent to my participation in this research project.

_______________   _______________________________

DATE   VOLUNTEER

_______________   _______________________________

DATE   WITNESS

APPENDIX B

MALE INFORMATION SHEET

PARTICIPANTS NAME:______________________________ AGE__________

DIAGNOSIS:______________________________________ SEX:_________

LIST OF PRESENT MEDICATIONS:

<u>MEDICINE</u>	<u>DOSAGE</u>	<u>TIME TAKEN</u>

TEST RESULTS:

<u>TRIAL 1</u>

DATE:__________________

BODY WEIGHT:___________

SKIN FOLD MEASUREMENTS: (mm)

CHEST_______________

ABDOMEN_____________

THIGH_______________

CIRCUMFERENTIAL MEASURES: (m)

WAIST_______________

FOREARM_____________

<u>TRIAL 2</u>

DATE:__________________

BODY WEIGHT:___________

SKIN FOLD MEASUREMENTS: (mm)

CHEST_______________

ABDOMEN_____________

THIGH_______________

CIRCUMFERENTIAL MEASURES: (m)

WAIST_______________

FOREARM_____________

APPENDIX C

FEMALE INFORMATION SHEET

PARTICIPANTS NAME:______________________ AGE:__________

DIAGNOSIS:______________________________ SEX:__________

LIST OF PRESENT MEDICATIONS:

MEDICINE	DOSAGE	TIME TAKEN

TEST RESULTS:

TRIAL 1

DATE:________________
BODY WEIGHT:__________
SKINFOLD MEASUREMENTS:(mm)
CHEST____________
AXILLA___________
TRICEPS__________
SUBSCAPULA_______
ABDOMEN__________
SUPRAILIUM_______
THIGH____________

CIRCUMFERENTIAL MEASURES: (cm)
GLUTEUS__________

TRIAL 2

DATE:________________
BODY WEIGHT:__________
SKINFOLD MEASUREMENTS:(mm)
CHEST____________
AXILLA___________
TRICEPS__________
SUBSCAPULA_______
ABDOMEN__________
SUPRAILIUM_______
THIGH____________

CIRCUMFERENTIAL MEASURES:(cm)
GLUTEUS__________

APPENDIX D

ACTIVITY LEVEL ASSESSMENT CHART

IA = INACTIVE:	no regular physical activity with a sit-down job (e.g.hospital patients).
LA = LIGHT:	no organized physical activity during leisure time with three to four hours of walking or standing per day.
MA = MODERATE:	sporadically involved in recreational activities such as weekend golf or tennis, occasional jogging, swimming or cycling.
HA = HEAVY:	consistent job activities of lifting or stair climbing or participating regularly in recreational/fitness activities such as jogging, swimminng or cycling at least three times a week for 30 to 60 minutes per session.
VA = VIGOROUS:	participation in extensive physical activity for 60 or more minutes at least four days per week.

APPENDIX E

INDIVIDUAL SUBJECT DATA

SUBJECT	AGE	HEIGHT in.	WEIGHT kg.	SF1	SF2	BIA1	BIA2
1	49	62.0	55.45	32.2	31.9	30.0	31.0
2	62	61.8	56.59	31.8	31.9	33.0	32.0
3	60	62.5	59.54	34.0	34.1	34.0	34.0
4	49	57.5	78.64	39.7	39.7	43.0	43.0
5	59	65.5	64.09	31.6	31.6	27.0	28.0
6	65	64.0	70.90	34.0	34.3	36.0	36.0
7	54	63.0	46.82	16.8	16.1	20.0	19.0
8	75	67.0	67.73	22.6	23.2	24.0	25.0
9	63	66.5	76.36	24.8	24.8	24.0	30.0
10	67	69.0	79.09	28.6	28.5	33.0	34.0
11	63	72.0	77.27	25.5	25.0	18.0	20.0
12	48	74.5	86.82	20.8	20.8	21.0	22.0
13	58	71.0	86.14	20.5	20.4	22.0	22.0
14	68	66.0	77.95	27.0	27.1	30.0	31.0
15	58	68.0	87.27	25.8	26.4	19.0	19.0
16	64	72.0	106.82	33.4	33.0	31.0	32.0
17	59	73.5	92.04	24.8	24.7	29.0	26.0

BIA1= Percent fat measured from BIA, day 1
BIA2= Percent fat measured from BIA, day 2

SF1= Percent fat measured from skinfolds, day 1

SF2= Percent fat measured from skinfolds, day 2