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Tests for measurement of percent body fat in paraplegics

Zechar, Deborah Lee, Ph.D.
The Ohio State University, 1988

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TESTS FOR MEASUREMENT OF PERCENT BODY FAT IN PARAPLEGICS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of the Ohio State University

By
Deborah Lee Zechar, B.A., M.S., M.A.

*****

The Ohio State University

1988

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1988
DEDICATION

To my best friend, Garth
whose love and support kept me going.
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CHAPTER I

Introduction

Body composition assessment has proven to be a useful tool in determining optimal weights for individuals. Measurements of body composition permit the estimation of body fat and fat-free weight. When these components of body composition are in proper proportion, both sports performance and healthful living in general are enhanced.

Although height-weight tables are still widely used to assess the extent of "overweightness" based on age and "frame size", such tables do not provide information with regard to the relative composition or quality of an individual's body weight. Someone may weigh much more than the average weight-for-height standards based on insurance company statistics, yet still be "underfat" in terms of the body's total quantity of fat. The "extra" weight could simply be additional muscle mass. Although many larger-sized persons are indeed "overweight", they are not necessarily too fat and do not necessarily
need to reduce. Someone in this situation might jeopardize his or her overall health by undertaking a crash or bizarre diet that prohibited the proper intake of essential nutrients.

The fat content of the human body has physiological and medical importance. It may influence morbidity and mortality, it may alter the effectiveness of drugs and anaesthetics, and it may affect the ability to withstand exposure to cold and starvation. Thus the measurement of the total body fat provides useful information.

The total amount of fat in the body is made up of storage and essential fat. Storage fat is made up of primarily the lipid triglyceride and is the expendable nutritional supply in subcutaneous depots. The quantity of storage fat is similar in males and females. Essential fat represents lipids in bone marrow, deep fat stores, and intramuscularly as well as in the central nervous system, liver, heart, and other organs. Essential fat is sex specific with females having a greater amount of fat due to hormonal and reproductive functions. Essential fat also represents the lowest amount of fat that is needed for normal physiological function. Minimal body weight is the lean body mass plus the essential fat content of 3-5% in males and 9-12% in females.

Obtaining an accurate estimation of body
composition is not easily accomplished. The approach most commonly used to obtain precision with which one can estimate body composition is dependent upon obtaining accurate measures of underwater body weight and of the residual volume of air in the lungs at the time of weighing. Most underwater weighing systems involve the subject sitting in a suspended chair in a tank of water, exhaling maximally, bending over and going underwater, at which point the reading on the scale is taken. Care must be taken to obtain the needed accuracy, especially with exhaling, otherwise the determination of percent body fat is inexact. Water turbulence, and movement of the subject in the chair, may create sufficient scale oscillations to preclude any reasonable chance of obtaining an accurate reading.

Skinfold thickness as measured with a skinfold caliper determines the thickness of a double layer of skin and underlying fat deposits as the tissue is folded during the measuring process. Because skin thickness varies minimally from person to person, this procedure gives a reasonably accurate measurement of the subcutaneous fat thickness. Numerous researchers have developed equations for estimating accurately, by 95 - 97%, total body fat percentage from the sum of skinfold thickness measurements from selected sites.
Circumferences, taken with a tape measure, for anthropometric assessment can provide a wealth of information about physique. There is more consistency to the measurement process because of the ease of taking measurements. With proper anatomical location, there is relatively little margin for error. Using the equation by Wilmore and Behnke, diameters can be used to predict lean body weight.

Statement of the Problem

There is a need to measure body composition in a disabled group such as paraplegics. Nutritionists and physicians often need to know the ideal body weight for these patients when dealing with them in a clinical setting. Maintenance of a recommended body weight is important in wheelchair-dependent individuals, since excessive weight may predispose them to pressure sores and other skin and soft tissue changes. Equally important is the need to maintain adequate muscle mass for transfers and other activities of daily living. Reference values need to be established in order to make valid recommendations.

Underwater weighing is considered the "gold standard" against which all other methods are
compared for able-bodied populations. For disabled populations, however, it may not be valid. The results of a pilot study indicated that there is a vast difference between the scores of the subjects and controls on the underwater weighing and a vast difference between underwater weighing versus the skinfold and circumference measurements. By comparing the three main methods of determining body fat: underwater weighing, skinfolds, and circumferences and diameters; through the use of repeated measures ANOVAs, the most valid methods of assessing body fat for a disabled population can be determined.

The results of a pilot study have indicated that residual volume may be different in a disabled population compared to an able-bodied population. This could be a determining factor in the difference in underwater weighing scores between the disabled and the able-bodied. Therefore, residual volume and other pulmonary functions will be tested both in the air and in the water.

Purpose of the Study

The purpose of this study is to document and compare percent body fat as measured by various
methods. These methods are underwater weighing, skinfold thicknesses, and circumferences and diameters of spinal cord injured paraplegics. In addition, the discrepancies in underwater weighing scores of the able-bodied controls vs. the disabled subjects vs. the skinfold and circumference scores will attempt to be explained by examining residual volume and other pulmonary functions in the air and in the water.

Significance of the Problem

Very few published studies exist on body composition assessments of physically disabled people. Data from this study will lead to the establishment of reference values for this population, as well as determining the most valid technique for this population. Reference values will give health professionals a base from which to work. By determining which method of calculating percent fat is valid for a disabled population, health professionals will be able to ascertain their client's percent fat and put them on a diet if
necessary. The client's progress can be monitored by calculating percent body fat. Body composition studies can help determine the trophic effects of paralysis. The composition of the body is clearly related to health and the ability to do work. These criteria will help in the clinical setting as well as in every day life for the patient. Such information may ultimately lead to a higher level of rehabilitation.

Specific Aims

1. To determine and to compare the percent body fat in subjects with paraplegia due to spinal cord injury and in paired normals.

2. To estimate and compare percent body fat in subjects by circumference, skinfold, and underwater weighing methods--using two equations within each method.

3. Preliminary trials suggested that underwater weighing methods overestimate percent body fat in paraplegics, and that the "weakest link" in the underwater weighing method is in estimation of body density using residual volume; therefore measure and
compare residual volumes in impaired and normal subjects.

Definitions of Terms
(Lamb, 1984, pp. 464-476)

Body composition - the proportion of fat and lean constituents of the human body.

Body density - the weight of the body per unit volume; typically expressed in grams per cubic centimeter.

ERV - expiratory reserve volume; the volume of gas that can be expired from the end of tidal volume to residual volume.

FRC - functional residual capacity; is the volume of the lung at the end of expiration during normal breathing.

Hydrostatic weighing - underwater weighing used to determine body volume, which is in turn used to determine body density and body composition.

Lean body mass - the body mass that does not include fat tissue; muscles, bones, organs, etc.
Lipid = fat, especially triglycerides.

Obesity = excess body fat; forty percent or greater.

Residual volume = the volume of air in the lungs and gastrointestinal tract following a most vigorous exhalation that must be taken into account when determining body composition.

Skinfold technique = a method of estimating body fat by measuring subcutaneous fat with skinfold calipers.

TLC = total lung capacity, the volume of air in the lungs at the end of a maximal inspiration.

Trophic = growth

VC = vital capacity, the maximal volume of air forcefully expired after a maximal inspiration.
Quantification of body fat is needed not only for studies on the nature and treatment of obesity, but also for a variety of investigations that range from the assessment of nutritional status to the determination of a patient's response to a variety of diseases and metabolic disorders (Cohn et al., 1981). The deviation of body weight from the "standard" for height, sex and age, is a gross indicator of under- or over-development of soft tissues (Brozek, 1961). It is essential to understand changes in body composition in two groups of critically ill patients: one, where fluid losses or gains are large, and two, surgical patients with metabolic or nutritional problems (Hill, 1978).

Total body fat is not measured directly by use of any technique, according to Akers and Buskirk (1969), but is computed from mathematical relations and physiological assumptions, such as the amount of total body water, bone density, and intestinal gas. Nevertheless, it is accepted that total body fat is measured even when certain baseline assumptions have
been disproved and certain unknown factors have been
ignored. It is impossible to say how imprecise the
fat calculations really are, and one may never know
for sure. Animal dessication studies have been done,
but water content of the lean body mass varies with
species, so how can one accept that these values hold
for humans? Smith and Boyce (1977) conclude that
"Direct chemical analyses of humans have not been
done in sufficient numbers to obtain absolute values
of body composition." The inconsistencies in the
literature are numerous. Harsha's (1980) findings
indicate that each race and sex group requires
different standards in the estimate of body
composition, yet race is rarely considered. According
to Doxey (1984) there are limitations to skinfold
techniques- their effectiveness is decreased by
population specificity; and the predictibility of a
given equation requires that the subjects being
tested be similar to the research subjects in age,
sex, race, and physical fitness. Most researchers,
including Hill (1978), assume that in healthy people,
the composition of the lean body mass remains
constant, once the stage of physiological maturity is
reached. In surgical illness, under the influence of
some medications and in the aged, this has been shown
to vary considerably. For example, Garrow et
al. (1979) observed the water content of the fat-free
body of six adult cadavers to be 728, 733, 674, 730, and 704 g/kg, with the average of 725. This agrees well with the assumed value of 730 g/kg for the group, but values for individuals vary considerably. This tendency toward the mean is observed in any method which uses regression type equations, where accuracy on the individual level is sacrificed. According to Pollock and Jackson (1984), the value of the generalized equations over the linear equations is that they minimize large prediction errors that occur at the extremes of the body density distribution.

Jackson and Pollock (1978) concluded that the major weakness of the population specific equations was their inability to account for aging, and the non-linear relationship between subcutaneous fat and body density. Jackson and Pollock state that their accuracy is improved with the addition of circumference and diameter measures combined with skinfold and the use of populations of varied ages and degrees of body fatness.

Jackson and Pollock (1978) then suggest that the researcher needs to consider the ratio of subjects per variable, and consider that ten or more subjects per variable is ideal. On this basis alone, many published equations could be eliminated. Weltman and Katch (1978) and Katch and Katch (1980) claim to have
developed multiple regression equations which are not population specific.

The researcher agrees that the height/weight tables do not reflect what patients and physicians need to know. In many instances, all agree that body composition better indicates leanness than body height/weight (Doxey, 1984). With large muscular mass, loss of body weight to conform to the standard tables would require loss of lean body mass resulting in loss of strength and unwarranted physiological stress (Clark et al., 1977). According to Roche (1984), there is a widespread belief that the normality of body weight in adults should be judged according to frame size and recognized by the Metropolitan Life Insurance Companies. Roche (1984) states that the Metropolitan Life Insurance Company believes that, to judge the normality of weight in adults, the frame size category should be determined from elbow width. It has not been shown clearly that elbow width is related to body composition variables after the effects of weight and stature are removed.

According to Garrow (1982), there are no completely reliable values with which to compare the results of various studies of body composition. The values obtained by different techniques can only be compared to one another for consistency and theoretical soundness. Garrow (1982) believes that
"If patients are kept for several weeks in a metabolic ward with adequate facilities for calorimetry, it is possible to make quite accurate estimates of the change in body fat, either by energy balance or nitrogen balance" (Garrow, 1982). If two different methods are used to estimate the body fat of a group of subjects at the start, and again at the end of such a balance period, the difference between the two estimates should agree with the change in fat content obtained from the balance studies (Garrow, 1982). Smith and Boyce (1977) found that regression equations are less accurate when they are used to predict the body composition of a sample other than the one from which they are derived.

Bulbulian et al. (1987) discerned that even the generalized skinfold equations failed to adequately predict the body density in male paraplegic athletes, with the majority of equations over-predicting body density in paraplegic athletes. Diameter measures alone were not acceptable. Hydrostatic weighing can be affected by the loss of lean tissue in the lower extremities, changes in bone density, and fluid shifts which will affect the primary assumptions that are made regarding density of mineral, protein, and fat in the Siri equation (1961), which converts body density to percent fat.

In a paraplegic group, according to Bulbulian et
al. (1987), the presence of edema will tend to over-predict fat from body-density with as much as +4.3%. In addition, paraplegics tend to be mesomorphic. It has been shown that somatotype influences body composition prediction in young females, which adds additional reservations about generalized equations.

A good deal of prediction error associated with paraplegic athletes is due to the different origins of injury, the variance in degree of spasticity, variations in demineralization of the injured limbs and increase in bone density of the upper limbs, body fluid shifts, and length of injury or training to name a few. (Bulbulian et al. 1987)

Hydrostatic Weighing

Hydrostatic weighing is considered to be the most reliable method for body fat assessment, states Warner et al. (1986). It is based on the assumption that heterogenous lean tissue has a constant density equal to water. Fat is said to "float" and have a constant density also distinct from lean. It is then theoretically possible to measure the volume of a subject either from the volume of water displaced, or from the loss of weight as described by Archimedes (Behnke, 1961).

This method requires considerable subject
cooperation, as the individual must exhale completely and then submerge totally under water, up to ten times. The subject's weight in air and in water are compared. Values for air in the lungs and intestinal gas are taken into account because they contribute to the body's buoyancy. All of these figures are combined to produce a body density value, which is then converted into percent fat. This method is difficult, if not impossible, for use with the obese, elderly, or ill (Cohn et al., 1981).

The sources of experimental error in this measurement are said to be found in (1) consecutive trial testing, (2) measuring residual volume, and (3) intestinal gas content (Katch and Katch, 1980; Buskirk, 1961).

This method is sound theoretically, and is universally accepted as the "gold standard" for body composition studies. However, the biological constants which the researchers must accept are known to vary: one, water content; two, the protein to mineral ratio; three, density of fat tissue; and four, fat content (Katch and Katch, 1980).

Bone density is thought to be part of the constant of the fat-free or skeletal mass. It is now known to increase up to the age of twenty and decrease after fifty (Durnin, 1974; Brozek, 1961). In addition, the density of any one bone segment was
found to vary enough to make it a poor indicator of total skeletal density. Mazess (1964), however, has indicated that the use of nearly monochromatic radiation for the direct determination of bone mineral absorption works for bone with overlying tissue. While Cameron et al. (1968), have found that photodensitometry of radiographs is almost as accurate for bone mineral determination on excised bones as direct radionuclide photon absorption, accuracy was greatly reduced if the same materials were covered with soft tissue. Blacks are known to have average skeletal weight and densities greater than those of whites (Harsha, 1978; Garn, 1976; Durnin, 1974; Schutte, 1984). So we can be assured of the inaccurate body fat estimates of blacks, measured by hydrostatic weighing, since bone density measurements are not routinely conducted.

For field studies a portable scale can be used where a swimming pool is available. The movements in the water can cause fluctuations on the scale making it difficult to control. According to Williams et al. (1984), underwater weighing using a Hubbard tank is equally as effective as using a standard tank.

Other components of underwater weighing that are determinants in calculating the percent body fat include residual volume and intestinal gas. Assessment of residual volume requires additional
equipment since we know that the air in the lungs contributes to the buoyancy of the body. Constants can be used for this value, but are less accurate than an actual measurement. Both helium dilution and nitrogen washout technique are valid means to make this assessment.

It is known that intestinal gas is a factor to be considered in underwater weighing, but to date is not being measured directly. A single constant is used to account for this factor (Goldman and Buskirk, 1961).

In recent years improvements have been developed which attempt to deal with several sources of error, in underwater weighing, which include subject distress and residual lung volume assessment. Garrow (1979) discusses a device in which the subject is immersed only to neck level and the head is covered by a clear plastic lid. The air space around the head is then measured by observing the volume change which is necessary to cause a given change in pressure. Garrow (1979) feels that this will help subjects that suffer from difficulty in submerging under the water.

Smith and Boyce (1977), in an attempt to avoid subject distress, have their subjects breathe through a snorkle, then hold their breath for five seconds. Akers (1969), too, assesses residual volume while the subject is not submerged. The subject breathes room
air, and then oxygen, while his expired air travels outside of the weighing tank to a collecting spirometer during the seven minute washout period.

Akers (1969) also uses an electronic load cell, rather than a dial scale, which produces a graphic record and avoids the possible errors from a fluctuating scale pointer, in order to increase accuracy in the underwater weighing process.

Despite the biological and experimental errors inherent in this method, it is this method to which all others must be compared themselves if they hope to be validated. Lohman (1981) estimates the standard error for hydrostatically determined percent fat to be 2.5%. Katch and Katch (1980) claims that the hydrostatically determined body density error is +/- 3.8%.

ANTHROPOMETRY

Skinfold

Measuring skinfold thicknesses at various body sites is the most common method used today to estimate body fat. The basis of this method is that skinfold measurements at selected sites on the body surface not only provide a good estimate of total subcutaneous fat but also proportional to total body fat. This method requires considerable technician
training if measurements are to be repeatable and takes several minutes to perform (Katch and Katch, 1984). Minimal cooperation, on the subjects' part is required, as compared to underwater weighing; they must wear halter tops and shorts so that body sites are exposed.

The limitations of this technique are many. The basic assumption of a constant ratio of subcutaneous to total fat is questionable. The ratio decreases with aging (Smith, 1977) and fat storage is said to change from peripheral to deep areas in chronic undernutrition (Spurr, 1981).

It is difficult to measure obese subjects because of the limited opening ability of the calipers. Also the table of Durnin and Wormersly (1974) does not cover very fat subjects. A major source of measurement error lies in the intertester variability, according to Garrow (1982). Cohn (1981) and Brozek (1961) points out that there is a variation in the compressibility and fat content of subcutaneous tissue, and in the thickness of the skin. Mayhew et al. (1985) found in their study, that the most satisfactory equation was the Jackson-Pollock generalized formula.

Cohn (1981) compared five methods of estimating body fat, and found the mean skinfold measurements consistently lower than the other methods- body
water, underwater weighing, total body nitrogen, and total body potassium. The only variations within this method are found in, one, the type of caliper used, two, the sites of measurement, and three, what, if any, additional anthropometric data is included, such as girths or breaths. Most testers (Laubach et al. 1981, Doxey 1984, Jackson & Pollock 1978, and Hill et al. 1978) include subscapular, triceps, biceps, and supra-iliac skinfolds. In the use of plastic calipers compared with Harpenden calipers, the calculated percent fat differences were less than 1% among calipers according to Pollock and Jackson (1984).

A preliminary report by Martin et al. (1981) showed that the variability of bone, muscle and fat density and total body water in male and female cadavers is greater than originally assumed. Thus, if the predictability of percent fat becomes more suspect, the use of the sum of skinfolds as a standard may become more important (Martin et al., 1981).

Cardus et al. (1985) determined the body composition of 45 patients with spinal cord injuries versus 12 able-bodied, healthy controls through the use of the total body water technique, employing radiographic tracers. The spinal cord injured patients had lower absolute amounts of water, fat and protein content, but no differences in the amounts of
these components when expressed relative to gross body weight. The amount of bone mass constituted a higher percentage of the gross body weight, contributing to a higher density of these patients.

The loss of body weight following spinal cord injury is primarily due to a loss of water, fat, and protein.

In the study by Dolbow (1985), the skinfold thickness and circumference measurements of subjects with hemiplegia were evaluated. The impaired arms were consistently smaller in circumference but larger in skinfold thickness measurements than the non-impaired arms. The consistent differences in measurements between the impaired and non-impaired arms indicated that estimation of total body fat percentage was unreliable when measurements were taken of the impaired extremities, regardless of which side of the body was chosen. The greatest influence in the measurement differences appeared to be the degree of paralysis.

Possible reasons for the size difference of the impaired arms include: one, the build-up of interstitial fluid (edema) in the impaired extremities and two, a reduced utilization of energy stores in the impaired extremities (Dolbow, 1985). The second point is believed to be due to "impaired blood flow does affect fatty acid mobilization and
may consequently cause a variance in skinfold thickness because the adipose tissue in the impaired arm may be metabolized at a much slower rate in the nonimpaired arm" (Dolbow, 1985).

According to Laubach et al. (1981), the anthropometry of aged male wheelchair-dependent patients was similar to ambulatory veterans of the same age in the areas of stature, total body fat percentages and limb circumferences. In dissimilarity, the wheelchair-dependent subjects had smaller upper body skinfolds, and greater body weight, trunk circumferences, lower body skinfolds and handgrip strength.

Circumference and Diameter Measurements

Considerable interest has been directed toward the development and validation of composition prediction equations using anthropometric variables because of the ease of taking measurements (Ward, 1984). At least 100 equations have been reported in the literature predicting the change in whole body composition as a function of changes in the subcutaneous fat layer. For most, if not all of the equations, the criterion variable is body density, which in itself is an imperfect estimator of body composition (Ward, 1984). The major statistical
pitfall using the multiple regression technique is that any given multiple R does not necessarily mean that a particular regression equation will show the same degree of success in accurately predicting individual scores from a second set of data (Katch, V., 1983).

Davis (1985) found that a valid predictive equation for adult males utilizing the individual's age, waist girth, and height correlated .9 with underwater weighing, making it possible to easily measure large groups. Wilmore and Behnke (1969) discovered that the majority of the skinfolds and several of the circumferences showed a relatively substantial relationship with body density. In addition, the majority of the diameters and circumferences showed a relatively high relationship with lean body weight.

**Pulmonary Function**

The residual volume (RV), defined as the volume of air remaining in the lungs following the greatest possible maximal expiration, is the only fractional lung volume which cannot be directly assessed through conventional spirometric analysis. Consequently, the measurement of residual volume is accomplished only
through some form of indirect analysis (Wilmore, 1969).

When a person is immersed in water up to his neck, two influences on lung function occur: 1) a gradient of hydrostatic pressure counteracts the force of the inspiratory muscles and deforms the chest wall inward when the muscles are relaxed, and 2) blood shifts into the thorax due to the compressive effect of the water on the blood vessels of the extremities. Both effects decrease total lung capacity (TLC) and vital capacity (VC). The hydrostatic pressure decreases TLC and VC by limiting the force available for inspiration and the blood shift decreases them by decreasing the compliance of the lung due to congestion and by replacing air in the thorax with blood (Robertson et al. 1978).

Timson and Coffman (1984) feel that it is important to measure total lung capacity (TLC) while the subject is submerged in water to take into account the compressing effect that hydrostatic pressure has on TLC, VC, and other lung volumes. They determined significant differences between TLC and RV on land and in the water of 2.0% body fat for males.

Gibbons et al. (1985) determined that RV measurements taken in the water on a group of college-aged females produced more accurate results than RV done in the air.
Underwater weight assessed at FRC versus RV showed no difference in bone density or percent fat values (Thomas and Etheridge, 1980).

According to Buskirk (1961), some investigators have used estimated values for RV in their calculations of body density. Other investigators have determined RV before or after the underwater weighing procedure has been carried out. While an experiment may not require a determination of RV at the time of underwater weighing for better accuracy of body density (when larger groups are studied), it should be emphasized that assuming RV may yield errors of approximately 200-300ml due to trapped air behind closed airways. If RV is assumed, the effect of age, sex, and posture should be considered. Latin et al. (1986) compared RV and predicted RV of 25 men during underwater weighing. The correlation between the two was low and non-significant. Predicted RV's that are smaller than the actual RV result in an underestimation of body density and therefore an overestimation of percent body fat. Wilmore (1969), Morrow et al. (1986), Hackney et al. (1985); and Etheridge et al. (1978) also found that measured residual volume introduces little percent fat error while predicted RV introduces a substantial source of measurement error.

Marks et al. (1986) states that a given absolute
error in RV would have a greater effect on percent body fat calculations for small individuals (with a small RV and small body weight) than for large individuals.

Bondi et al. (1976) found that functional residual capacity decreases during immersion in water which resulted in the impingement of closing capacity on the tidal volume. Airway closure occurs during tidal ventilation in immersed subjects and may result in impaired gas exchange.

Lung volumes in Black subjects are 10-15% lower than in sex, age, height, and weight-matched Caucasians, according to Cerny (1987). The differences of the respiratory pressure-volume relationships may be due to Black subjects breathing higher on their pressure-volume curve.

In summary, a measured RV is deemed to be more accurate than a predicted one. Submerging a subject in water produces a compressing effect on the chest and thus alters lung volume.
Figure 1

The normal spirogram and subdivisions of lung volume. (Gong, p.35)
CHAPTER III

Methods and Procedures

Selection of Subjects

The subjects for this study were 8 male spinal cord injured paraplegic volunteers between the ages of 19-54 ($\bar{x} = 37 \pm 9.4$). Information on each subject's age, years of impairment, and degree of paralysis was obtained so possible similarities could be compared and contrasted.

There were also eight able-bodied controls matched for age $\pm 4$ yrs., sex, weight $\pm 10\%$, height $\pm 3''$, and race. They underwent the same tests as the group of subjects.

Research Design

The research design was Campbell and Stanley's (1963) number eleven, the counterbalanced design. The only threat to internal validity was the threat of interaction of selection and maturation. Because the
second trial occurred within five days of the first, this threat was controlled. The threat to external validity was the threat of multiple treatment interference. This was controlled by the fact that the treatments were physiological parameters, uncontrollable by the subjects. This design is indicated for groups where random assignment of subjects is not possible.

Intra-examiner agreement was obtained by testing on Day 1 and Day 2.

Assumptions
1. That the 3 methods of determining percent body fat used in this study are valid methods for an able-bodied and disabled populations.

2. That body density determined by underwater weighing in paraplegics is equal to the body density of controls.

3. That intestinal gas is the same in paraplegics and able-bodied.

4. That the number of years the person was disabled and the level of injury did not affect the study.
Preliminary Procedures

Eight male spinal cord injured paraplegic subjects, ages 19-54, were tested on two separate occasions for residual volume using the helium dilution method, hydrostatic weighing, skinfolds and circumferences and diameters. The 8 controls underwent these same tests.

Human subjects approval was obtained with protocol number 86H0152. A signed statement from each subject and control allowed participation and consent for the procedures.

Statistical Methods

Data was analyzed using a 2 x 3 x 2 repeated measures ANOVA design with one factor nested. The 2 is controls vs. subjects; the 3 is three methods for determining percent body fat (skinfolds, circumferences, underwater weighing); and the 2 is each type of equation for each method (ex.: Sloan and Jackson-Pollock for skinfolds). Because this is a nested ANOVA, a different equation to determine degrees of freedom was used rather than the equation for the more common crossed ANOVA. There are a total of 95 degrees of freedom. Degrees of freedom
identifies the basic ratios required to calculate the sum of squares.

For the measurement of percent body fat, the dependent variable is the percent body fat. The independent variables are 1) the three methods of measuring (skinfolds, circumferences, and underwater weighing); 2) within each method the two types of formulas; 3) subjects vs. controls.

For the measurement of lung capacities, the dependent variable is the volumes. The independent variables are 1) subjects vs. controls; 2) different lung capacities (VC, RV, FRC, TLC, ERV); 3) wet vs. dry condition.

**Methods**

**Hydrostatic Weighing**

Each subject was weighed in air on a balanced wheelchair scale (kg.). Stature was measured in the standing position with the individual supported by a tilt top table at 80 degrees and in the seated position (on the table, with a board under the buttocks) using a standard cloth tape (cm) according to Laubach et al. (1981). Prior to underwater weighing, vital capacity (liters) and residual volume were determined using the spirometer and helium.
dilution respectively.

Hydrostatic weighing was performed in a swimming pool 20' by 30' with a constant water temperature of 31.11 degrees celsius. An overhead steel track, permanently attached to the ceiling, supported the circular Medic Detecto Kilogram scale and underwater weighing chair which was suspended into the water. The subjects entered the chair on the deck. The chair was moved along the overhead track until it was above the water. The chair was then lowered into the water. A spotter was on each side of the subject to assure the subject that he would not fall out of the chair and be unable to get up. The subjects exhaled maximally and then bent over, completely submerged, while the reading was taken. This process was repeated from 5 to 10 times or until a trend line of underwater weighing leveled off. Jackson, Pollack & Ward (1980). An average of the last two or three weighings (grams) was taken.

Body density was determined as described by Katch (1969), Wilmore (1969). Body composition, consisting of lean body weight and fat weight can be determined after the percent fat is calculated using the Siri (1961) equation

\[ \frac{495}{\text{Body Density}} - 450 = \text{percent body fat} \]

A lightweight swimming suit was worn throughout the testing. Water temperature was recorded to correct for density of water at weighing.
Skinfold Thickness

The skinfold measurement process to be implemented is the one developed by Jackson and Pollock (1978), using a generalized equation. Generalized equations minimize large prediction errors that occur at the extremes of the body density distribution.

One person made all the measurements on both subjects and controls. According to Pollock & Jackson (1984) "it appears that intra-tester reliability can be attained rapidly with good instruction and practice; however, the exact amount of practice to become proficient in measuring skinfolds has not been clearly documented. Some degree of accuracy has been reported after a couple orientation and practice sessions, while some experts recommend practice with 50 to 100 subjects is necessary. Others also stress the importance of multiple measurements on each skinfold site with a minimum of 2-5 trials being averaged" (p. 610). The subjects were measured in the recumbent position. Skinfold thicknesses were from five sites at least
three times each. There was never a difference of
more than 1 mm taken from the same site. Lange
skinfold calipers were used. Care was taken to locate
each site precisely and mark it with a pen, and to
maintain a constant distance between the caliper and
the thumb and finger holding the skinfold.
Measurements were made from both sides of the body,
noting the impaired locations, such as an atrophied
limb.

The five sites include: Chest- over the lateral
border of the pectoralis major, just medial to the
axilla, fold running diagonally between the shoulder
and the opposite hip; Subscapular- inferior angle of
the scapulas with the fold running parallel to the
axillary border; Triceps- midway between the acromion
and olecran processes on the posterior aspect of the
arm, the arm held vertically, with the fold running
parallel to the length of the arm; Abdominal-
horizontal fold adjacent to the umbilicus; Thigh-
vertical fold on the anterior aspect of the thigh
midway between the hip and knee joints (Behnke and
Wilmore, 1974).

Circumferences and Diameters

The circumference and diameters were taken in
the recumbent position. These include: Chest
circumference- nipple line at mid-tidal volume in the males; Waist circumference- laterally, at the level of the iliac crests, and anteriorly, at the umbilicus; Biceps circumference (flexed)- maximal girth of the mid-arm when flexed to the greatest angle with the underlying muscles fully contracted; Forearm circumference (flexed)- maximal girth with the elbow extended and the hand supinated; Calf circumference- maximal girth; Diameters include: Biacromial diameter- distance between the most lateral projections of the acromial processes with the elbows next to the body and the hands resting on the thighs; Bideltoid diameter- distance between the outermost protrusions of the shoulder with the anthropometer making only light contact with the skin; Chest width- arms adducted slightly for placement of the anthropometer at the level of the fifth to sixth ribs (nipple line in men); Arms adducted back to the side of the body for the measurement; Bi-iliac diameter- distance between the most lateral projections of the greater trochanters; Knee- distance between the outermost projections of the tibial condyles, with the knee flexed to 90 degrees; Ankle- distance between the malleoli with the anthropometer pointed upward at a 45 degree angle; Elbow- distance between the condyles of the humerus with the elbow flexed and hand supinated;
Wrist- distance between the styloid processes of the radius and ulna (Behnke and Wilmore, 1974).

Circumferences were measured with a metal tape (cm.). A broad blade anthropometer was used to measure body diameter (cm.).

Pulmonary Functions

Residual volume was determined by using the helium dilution technique. It was done both in the air and in the water. In the water, the subject was in a seated position with water up to the larynx.

Any subject having acute respiratory symptoms, using bronchodilators, or ingesting solid food less than three hours prior to testing, was excluded. Prior to each set of lung volume measurements, a known volume of 3.000 liters with less than 1.0 percent error, was measured to calibrate the equipment. Using the constant volume helium dilution technique described by Hathirat (1970) and in a seated position without binders, orthoses, or restrictive clothing, the functional residual capacity (FRC) was measured on two separate days.

Helium equilibration was established when helium concentrations change less than 0.02 percent in a 30-second interval (Ferris, 1978). As suggested by
Goldman (1959) 100 milliliters from the calculated FRC was subtracted for helium absorption, respiratory quotient and nitrogen increment. At the end of the helium dilution procedure, each subject repeatedly exhaled his expiratory reserve volume (ERV) until the larger two volumes agree within 10% or 200 milliliters, whichever was greater. The FRC and ERV were corrected to BTPS conditions and the largest ERV were subtracted from the FRC to obtain the Residual Volume (RV).

Using age, height, weight, and body surface area, the predicted normal FRC and RV was determined using the regression equations of Goldman (1959). The percent predicted FRC and RV for each subject was calculated.
Table 1
Equations Used to Estimate Percent Fat

Predicted Height (Churchhill et. al. 1981)

\[ 1.35 \times \text{sitting height (cm.)} + 53.46 = \text{P.H. (cm.)} \]
\[ \text{P.H.} = \text{Predicted height} \]

Underwater Weighing (Goldman and Buskirk 1961)

\[
\frac{\text{Wa}}{\left( \frac{\text{Wa} - \text{Ww}}{\text{DH}20} \right) - (RV + .1)} = \text{Body Density (B.D.)}
\]

\[ \frac{495}{450} = \% \text{Fat (Siri, 1961)} \]
\[ \text{B.D.} \]

\( \text{Wa} \) = weight in the air

\( \text{Ww} \) = weight in the water

\( \text{DH}20 \) = density of the water

Skinfolds

Sloan:

\[ \text{B.D.} = 1.1043 - 0.00133(\text{thigh}) - 0.00131(\text{subscapular}) \]

\[ \% \text{Fat} = 4.57 - 4.142 \times 100 \text{ (Brozek, Anderson, Keys)} \]

\[ \text{B.D.} \]

Jackson & Pollock Generalized:

\[ \text{B.D.} = 1.1093800 - 0.0008267(\text{sum}) + 0.0000016(\text{sum x sum}) - 0.0002574(\text{age}) \]

\( \text{sum} \) = chest, abdomen, thigh

\[ \% \text{Fat} = \text{Brozek, Anderson, & Keys equation} \]

Circumferences

Behnke:

\[ \text{LBW} = .204 \times h2 \text{ (decimeters)} \]

\[ \% \text{Fat} = \text{body weight (kg.)} - \text{LBW} \times 100 \]

\[ \text{body weight (kg.)} \]
Table 1 continued:

LBW = lean body weight

h = height

Wilmore & Behnke:

LBW (kg.) = 44.636 + 1.0817(body weight in kg.) - 0.7396(abdominal circumference in cm.)

% Fat = 100 - (100 x LBW)

body weight in kg.
### TABLE 2

A Comparison of the Subjects vs. the Controls

<table>
<thead>
<tr>
<th></th>
<th>Subjects</th>
<th>Control</th>
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<th></th>
<th></th>
<th>t</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Age, yrs.</td>
<td>37 ±10.3</td>
<td>34 ±11.06</td>
<td>3.89</td>
<td>4.18</td>
<td>0.53</td>
<td>&gt;0.05</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>5'7&quot; ±2.6&quot;</td>
<td>5'9&quot; ±2.3&quot;</td>
<td>0.98</td>
<td>0.87</td>
<td>-1.53</td>
<td>&gt;0.05</td>
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<tr>
<td>Weight, lbs.</td>
<td>196 ±39.86</td>
<td>194 ±32.82</td>
<td>15.04</td>
<td>12.38</td>
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Table 3
Percent Body Fat by Three Methods

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<th>Method</th>
<th>Subject</th>
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<tr>
<td>Skinfolds:</td>
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<tr>
<td>J&amp;P equation</td>
<td>19.6 ±7.66</td>
<td>17.6 ±7.63</td>
</tr>
<tr>
<td>Sloan equation</td>
<td>24.4 ±10.7</td>
<td>22.6 ±11.2</td>
</tr>
<tr>
<td>Circumferences:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W&amp;B equation</td>
<td>20.5 ±7.8</td>
<td>16.4 ±6.2</td>
</tr>
<tr>
<td>Behnke equation</td>
<td>30.6 ±15.34</td>
<td>27.3 ±10.7</td>
</tr>
<tr>
<td>Underwater Weighing:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>37.4 ±9.14</td>
<td>24.1 ±9.42</td>
</tr>
<tr>
<td>Wet</td>
<td>38.4 ±7.24</td>
<td>23.8 ±9.93</td>
</tr>
</tbody>
</table>

a F = 7.13, p 0.025
b F = 32.52, p 0.01
c F = 0.03, p 0.25
### TABLE 4

A Comparison of the Lung Functions of the Subjects vs. the Controls

<table>
<thead>
<tr>
<th></th>
<th>Subjects</th>
<th></th>
<th>Controls</th>
<th></th>
<th>t</th>
<th>p</th>
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<td>SD</td>
<td>SEM</td>
<td>X</td>
<td>SD</td>
<td>SEM</td>
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<td>Vital Capacity, liters - L</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Dry</td>
<td>4.18 ±0.58</td>
<td>0.22</td>
<td>4.89 ±1.07</td>
<td>0.40</td>
<td>-1.54</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Wet</td>
<td>4.19 ±0.67</td>
<td>0.25</td>
<td>4.67 ±1.06</td>
<td>0.40</td>
<td>-1.02</td>
<td>&gt;0.05</td>
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<tr>
<td>Residual Volume, liters -</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>1.23 ±0.39</td>
<td>0.15</td>
<td>1.40 ±0.37</td>
<td>0.14</td>
<td>-0.85</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Wet</td>
<td>1.24 ±0.23</td>
<td>0.09</td>
<td>1.53 ±0.30</td>
<td>0.11</td>
<td>-2.07</td>
<td>&gt;0.05</td>
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<tr>
<td>Functional Residual Capacity, liters -</td>
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<tr>
<td>Dry</td>
<td>2.34 ±0.49</td>
<td>0.18</td>
<td>2.70 ±0.62</td>
<td>0.23</td>
<td>-1.29</td>
<td>&gt;0.05</td>
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<tr>
<td>Wet</td>
<td>1.78 ±0.34</td>
<td>0.13</td>
<td>2.02 ±0.37</td>
<td>0.14</td>
<td>-1.26</td>
<td>&gt;0.05</td>
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<tr>
<td>Total Lung Capacity, liters -</td>
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<tr>
<td>Dry</td>
<td>5.41 ±0.80</td>
<td>0.30</td>
<td>6.28 ±0.99</td>
<td>0.37</td>
<td>-1.81</td>
<td>&gt;0.05</td>
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<tr>
<td>Wet</td>
<td>5.43 ±0.78</td>
<td>0.29</td>
<td>6.14 ±1.05</td>
<td>0.40</td>
<td>-1.45</td>
<td>&gt;0.05</td>
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<tr>
<td>Expiratory Reserve Volume, liters -</td>
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<tr>
<td>Dry</td>
<td>1.10 ±0.27</td>
<td>0.10</td>
<td>1.30 ±0.60</td>
<td>0.23</td>
<td>-0.80</td>
<td>&gt;0.05</td>
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<tr>
<td>Wet</td>
<td>0.54 ±0.16</td>
<td>0.06</td>
<td>0.55 ±0.29</td>
<td>0.11</td>
<td>-0.08</td>
<td>&gt;0.05</td>
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<td>Circumferences:</td>
<td>Subject</td>
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</tr>
<tr>
<td></td>
<td>mean ±SD (SEM)</td>
<td>mean ±SD (SEM)</td>
<td>t</td>
<td>p</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf L</td>
<td>33.8 ±5.02 (1.89)</td>
<td>39.9 ±5.72 (2.16)</td>
<td>-2.13</td>
<td>&gt;0.05</td>
<td></td>
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</tr>
<tr>
<td>R</td>
<td>33.7 ±4.89 (1.85)</td>
<td>39.8 ±5.42 (2.05)</td>
<td>-2.21</td>
<td>&gt;0.05</td>
<td></td>
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<tr>
<td>Waist</td>
<td>95.8 ±13.27 (5.01)</td>
<td>89.1 ±9.35 (3.53)</td>
<td>1.09</td>
<td>&gt;0.05</td>
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<td></td>
</tr>
<tr>
<td>Chest</td>
<td>107.0 ±10.69 (4.03)</td>
<td>99.7 ±6.84 (2.58)</td>
<td>1.52</td>
<td>&gt;0.05</td>
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<td></td>
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<tr>
<td>Biceps L</td>
<td>38.4 ±3.87 (1.46)</td>
<td>33.0 ±3.58 (1.35)</td>
<td>2.71</td>
<td>&lt;0.05</td>
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<tr>
<td>R</td>
<td>38.8 ±3.80 (1.43)</td>
<td>33.9 ±4.62 (1.74)</td>
<td>2.17</td>
<td>&lt;0.05</td>
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<tr>
<td>Forearm L</td>
<td>32.2 ±3.08 (1.16)</td>
<td>28.3 ±3.50 (1.32)</td>
<td>2.23</td>
<td>&lt;0.05</td>
<td></td>
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<tr>
<td>R</td>
<td>31.9 ±2.32 (1.41)</td>
<td>30.2 ±5.13 (1.94)</td>
<td>0.71</td>
<td>&gt;0.05</td>
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<tr>
<td>Diameters:</td>
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<tr>
<td>Ankle L</td>
<td>6.9 ±0.54 (0.20)</td>
<td>7.0 ±0.53 (0.20)</td>
<td>-0.36</td>
<td>&gt;0.05</td>
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<tr>
<td>R</td>
<td>7.0 ±0.62 (0.23)</td>
<td>7.1 ±0.54 (0.20)</td>
<td>-0.33</td>
<td>&gt;0.05</td>
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<td>Knee L</td>
<td>10.7 ±0.83 (0.31)</td>
<td>10.0 ±0.68 (0.26)</td>
<td>1.71</td>
<td>&gt;0.05</td>
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</tr>
<tr>
<td>R</td>
<td>10.5 ±0.84 (0.32)</td>
<td>10.0 ±0.72 (0.27)</td>
<td>1.22</td>
<td>&gt;0.05</td>
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<tr>
<td>Elbow L</td>
<td>6.4 ±0.54 (0.20)</td>
<td>6.2 ±0.80 (0.30)</td>
<td>0.56</td>
<td>&gt;0.05</td>
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<tr>
<td>R</td>
<td>6.4 ±0.54 (0.20)</td>
<td>6.4 ±0.60 (0.23)</td>
<td>0.00</td>
<td>&gt;0.05</td>
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<tr>
<td>Wrist L</td>
<td>5.5 ±0.34 (0.13)</td>
<td>5.5 ±0.45 (0.17)</td>
<td>0.00</td>
<td>&gt;0.05</td>
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<tr>
<td>R</td>
<td>5.4 ±0.24 (0.09)</td>
<td>5.5 ±0.50 (0.19)</td>
<td>-0.48</td>
<td>&gt;0.05</td>
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<td>Girths:</td>
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<td>Bitrochanter</td>
<td>35.6 ±4.66 (1.76)</td>
<td>35.9 ±3.83 (1.45)</td>
<td>-0.13</td>
<td>&gt;0.05</td>
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<td>Bi-iliac</td>
<td>33.1 ±3.04 (1.15)</td>
<td>31.9 ±3.53 (1.33)</td>
<td>1.20</td>
<td>&gt;0.05</td>
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<td>Chest</td>
<td>37.7 ±4.33 (1.63)</td>
<td>35.3 ±2.60 (0.98)</td>
<td>1.26</td>
<td>&gt;0.05</td>
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<td>Biacromial</td>
<td>36.4 ±3.68 (1.39)</td>
<td>35.5 ±2.07 (0.78)</td>
<td>0.57</td>
<td>&gt;0.05</td>
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<td>Shoulder</td>
<td>51.5 ±4.18 (1.58)</td>
<td>48.3 ±3.56 (1.34)</td>
<td>1.55</td>
<td>&gt;0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6

A Measurement of Variables of Respiratory Function

<table>
<thead>
<tr>
<th></th>
<th>DRY</th>
<th></th>
<th>WET</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.E.</td>
<td>Mean</td>
<td>S.E.</td>
</tr>
<tr>
<td>controls</td>
<td>4.89</td>
<td>0.37</td>
<td>4.67</td>
<td>0.37</td>
</tr>
<tr>
<td>subjects</td>
<td>4.18</td>
<td>0.21</td>
<td>4.19</td>
<td>0.24</td>
</tr>
<tr>
<td>controls</td>
<td>1.40</td>
<td>0.13</td>
<td>1.53</td>
<td>0.10</td>
</tr>
<tr>
<td>subjects</td>
<td>1.23</td>
<td>0.14</td>
<td>1.24</td>
<td>0.08</td>
</tr>
<tr>
<td>controls</td>
<td>2.70</td>
<td>0.22</td>
<td>2.02</td>
<td>0.13</td>
</tr>
<tr>
<td>subjects</td>
<td>2.34</td>
<td>0.17</td>
<td>1.78</td>
<td>0.12</td>
</tr>
<tr>
<td>controls</td>
<td>6.28</td>
<td>0.35</td>
<td>6.14</td>
<td>0.37</td>
</tr>
<tr>
<td>subjects</td>
<td>5.41</td>
<td>0.28</td>
<td>5.43</td>
<td>0.28</td>
</tr>
<tr>
<td>controls</td>
<td>1.29</td>
<td>0.21</td>
<td>0.55</td>
<td>0.10</td>
</tr>
<tr>
<td>subjects</td>
<td>1.10</td>
<td>0.09</td>
<td>0.54</td>
<td>0.06</td>
</tr>
</tbody>
</table>

VC = directly measured
RV = FRC - ERV
FRC = directly measured
TLC = RV + VC
ERV = directly measured
# Table 7

Measurements of Respiratory Parameters

**Injury = Controls vs. Subjects**  
**Condition = Wet vs. Dry**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
<th>DF</th>
<th>F</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC</td>
<td>injury</td>
<td>1</td>
<td>2.45</td>
<td>.1617</td>
</tr>
<tr>
<td></td>
<td>condition</td>
<td>1</td>
<td>2.20</td>
<td>.1819</td>
</tr>
<tr>
<td></td>
<td>injury x cond.</td>
<td>1</td>
<td>3.74</td>
<td>.0945</td>
</tr>
<tr>
<td>RV</td>
<td>injury</td>
<td>1</td>
<td>1.98</td>
<td>.2023</td>
</tr>
<tr>
<td></td>
<td>condition</td>
<td>1</td>
<td>0.77</td>
<td>.0021</td>
</tr>
<tr>
<td></td>
<td>injury x cond.</td>
<td>1</td>
<td>0.71</td>
<td>.4259</td>
</tr>
<tr>
<td>FRC</td>
<td>injury</td>
<td>1</td>
<td>1.94</td>
<td>.2063</td>
</tr>
<tr>
<td></td>
<td>condition</td>
<td>1</td>
<td>27.82</td>
<td>.4103</td>
</tr>
<tr>
<td></td>
<td>injury x cond.</td>
<td>1</td>
<td>0.45</td>
<td>.5247</td>
</tr>
<tr>
<td>TLC</td>
<td>injury</td>
<td>1</td>
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<td>condition</td>
<td>1</td>
<td>0.36</td>
<td>.5669</td>
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<tr>
<td></td>
<td>injury x cond.</td>
<td>1</td>
<td>0.69</td>
<td>.4329</td>
</tr>
<tr>
<td>ERV</td>
<td>injury</td>
<td>1</td>
<td>0.72</td>
<td>.4228</td>
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<tr>
<td></td>
<td>condition</td>
<td>1</td>
<td>39.00</td>
<td>.0004</td>
</tr>
<tr>
<td></td>
<td>injury x cond.</td>
<td>1</td>
<td>3.09</td>
<td>.1223</td>
</tr>
</tbody>
</table>
Table 8

A Comparison of Percent Body Fat As Estimated by Three Different Methods for Subjects and Controls

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>F-value</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>2</td>
<td>0.38</td>
<td>.69</td>
</tr>
<tr>
<td>Subjects</td>
<td>2</td>
<td>6.42</td>
<td>.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>T-test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>21</td>
<td>-0.78</td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>-3.41</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>2.64</td>
<td>.05 p .01</td>
</tr>
</tbody>
</table>

Method 1 = skinfolds  
2 = circumferences  
3 = underwater weighing
Table 9

P-Values as Compared for the Three Methods

<table>
<thead>
<tr>
<th></th>
<th>SF</th>
<th>C</th>
<th>UWW</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>NS</td>
<td>NS</td>
<td>0.01</td>
</tr>
<tr>
<td>C</td>
<td>NS</td>
<td>NS</td>
<td>0.05</td>
</tr>
<tr>
<td>UWW</td>
<td>0.01</td>
<td>0.05</td>
<td>NS</td>
</tr>
</tbody>
</table>

SF = skinfolds
C = circumferences
UWW = underwater weighing
NS = not significant
CHAPTER IV

Results

The purpose of this study is to measure body fat of spinal cord injured paraplegics using underwater weighing, skinfold thicknesses, circumferences and diameter measurements. The study will also show the discrepancies in underwater weighing scores of the able-bodied controls versus disabled subjects, the skinfold and circumference scores will be explained by examining residual volume in the air and in the water.

Table 2 presents and compares data on both normal and impaired subjects. There were no differences in age, height or weight between normals and impaired, all subjects were males, and the ratios of caucasian to black were the same between groups.

Tables 3, 4, and 5 present and compare percent body fat as measured by 3 methods (skinfold, circumference, underwater weighing) and 2 subtypes of each method. Except with the two underwater methods, there were no differences in estimated percent fat within each method between normals vs. impaired. That is, percent fat of normals and impaired subjects did not differ for any method involving either skinfold subtypes or circumference subtypes. For the purpose of comparing percent body fat, estimates were derived by skinfold and circumference methods. The impaired
and non-impaired subjects were then combined and the subtypes of each were compared. For the skinfold subtypes, the J & P equation gave a significantly smaller percent body fat than did the Sloan equation (p < 0.025). For the circumference subtypes, the W & B equation gave a significantly smaller percent body fat than did the Behnke equation (p < 0.01).

With either method of underwater weighing, estimated percent body fat for the impaired was significantly greater than for the normals (p < 0.05). There were no significant differences in percent body fat estimated by the "dry" or "wet" methods.

Table 9 displays p-values obtained for comparisons of percent body fat derived by the three methods. Mean estimates derived from skinfold measurements did not differ significantly from those derived from circumference measurements in either the normal or impaired individuals. However, underwater weighing produced percent body fat estimates higher in the impaired subjects than were derived using the other two methods. This difference did NOT appear in the normal subjects.

Because differences in percent body fat were estimated by the two methods of underwater weighing, both of which require estimation of residual volume, the parameters necessary for estimation of residual volume (i.e. vital capacity, functional residual
capacity) were compared to determine were the differences might have arisen. Table 4 displays and compares parameters of pulmonary function in both normals and impaired as measured by the "wet" and "dry" methods. There were no significant differences in any of the parameters between normals and impaired. Between the two subtypes, "wet" and "dry" there was significance for the ERV. The equation for underwater weighing (Goldman and Buskirk, 1961) is:

\[
\frac{Wa - Ww}{DH20} = \text{Body Density (BD)}
\]

\[
% \text{Fat} = \frac{495}{BD} - 450 \quad (\text{Siri, 1961})
\]

However, residual volume-- a most important determinant of estimation of percent body fat by this general methodology-- tended to be smaller in impaired vs. normal subjects \((0.1>p>0.05)\). This would generate a lower body density which would result in an overestimation of percent body fat in the impaired subjects.
Discussion

Limitations of this Study

One limitation to this study is the relatively small number (i.e. 8) of subjects impaired by spinal cord injury, and the variability in length of time and the level of the spinal injury. It is not known whether level of spinal cord injury affects distribution and/or amount of body fat. Although there are many such injured subjects, it is extremely difficult to recruit them considering the necessity of their coming to the facility twice and subjecting them to immersion under water. Another limitation lies in the relatively great variability in age of the subjects—from 19 to 54 years of age. As a person ages, compressibility of the skin fold changes at varying rates at different positions on the body. For example, compressibility of skinfold over the calf increases; while that over the scapula decreases.

General Discussion

The purpose of this study was to estimate percent body fat by underwater weighing, skinfold thicknesses, and circumferences and diameter measurement of spinal cord injured paraplegics. In comparing discrepancies in underwater weighing scores
of the able-bodied controls versus the disabled subjects, the skinfold and circumference scores were compared to the underwater weighing scores. By examining residual volume in the air and in the water, the discrepancies were explored.

One purpose of this study was to determine if percent body fat in subjects impaired by spinal cord injury differed from that in normals. It was demonstrated (Table 2) that the impaired population matched, quite closely, the normal population in weight, height, age and race. Thus, if any differences existed, they could not have been attributable to these factors. Percent body fat as measured by both circumferences and skinfold methods-and utilizing 2 equations for each method, did not differ between impaired and normals. Furthermore, percent body fat as estimated by both circumference and skinfold methods did not differ. Since both circumference and skinfold methods utilize measurements of structures (eg. upper arm, waist) in common, it was anticipated that values of percent body fat should be similar by these two methods.

The Jackson-Pollack Generalized equation was chosen because it is used by most researchers. Bulbulian et. al. (1987), used 12 different equations, including generalized equations, in their study. Bulbulian et al. (1987), felt that the
equations failed to adequately predict the body density in male paraplegic athletes. The majority of the equations over-predicted body density. Until some equations are developed for paraplegics, equations for the able-bodied will have to be used as a starting point.

The same could be stated for the circumference measurements; that the equations were developed on an able-bodied population. Height, body weight, and abdominal circumferences were the factors used in the equations. These factors tend to be less influenced by the paraplegics' condition than the factors used in the skinfold equations. It appears that it may not matter that these equations were developed for able-bodied populations.

It is somewhat surprising that percent body fat was similar for impaired and normals; since the equations on which the estimation is based were developed for normal subjects. Quite clearly, the thighs of impaired persons were atrophied, and the ratio of fat to muscle contributing to the total circumference should be different between the two groups.

The percent body fat of paraplegics could be different due to a number of factors:
1. A loss of bone density in the lower limbs
2. atrophy of the legs
3. the water content (edema) of the legs
4. the different origins of injury
5. the variance in degree of spasticity
6. an increase in bone density of the upper limbs
7. body fluid shifts
8. the length of time injured
9. the age at onset of injury

Percent body fat in normals as measured by underwater weighing did not differ from percent body fat as measured by either circumference or skinfold methods. However, this parameter was significantly greater for the impaired population when measured by the underwater weighing method. It was preconceived before this study, that impaired persons have greater fat content than normals. Two of the 3 methods refuted that; however, the underwater weighing method supported the preconception. What is the truth? Could it be that the underwater weighing method was the only correct method for the impaired, but gave an incorrect percentage—as did the other two methods—for normals?

If it is presumed that the other two methods and the underwater weighing method were correct for the normals, and that the circumference and skinfold methods are correct for the impaired; then it is true that the impaired have a percent body fat similar to normals, and that the underwater weighing method
overestimates—even though giving a value consistent with the preconception—percent body fat in the impaired. Why could the underwater weighing overestimate percent body fat?

Measurement of percent body fat by the underwater weighing method depends upon estimating body density; and estimation of body density by this method requires estimating residual volume of air in the body at the end of a most forced expiration. All other determinants (e.g., weight in the air, density of water, weight in the water) of estimation of percent body fat by the underwater weighing method are probably made with little error. It was preconceived that impaired persons may not be able to exhale vigorously enough to achieve a correct residual volume; since such a vigorous exhalation requires recruitment of accessory muscles of ventilation including muscles of the limbs and abdomen. Quite obviously, in the impaired population, these muscles function at less than optimal. Results of this study show a trend to a smaller residual volume in the impaired than in the normals; but the differences did not achieve statistical significance. Such an underestimate of residual volume in the impaired would have resulted in an overestimation of percent body fat in that group as compared with the normals. It is not known whether impaired subjects trap more
or less gas in their intestinal tract and within bone than normals. Since this volume is approximated yet contributes to the buoyancy of the subjects, this may impose an error in the estimation of residual volume and therefore percent body fat.

Robertson et al. (1978) found that when a person is immersed in water up to his neck, two influences on lung function occur: 1) a gradient of hydrostatic pressure counteracts the force of the inspiratory muscles and deforms the chest wall inward when the muscles are relaxed, and 2) blood shifts into the thorax due to the compressive effect of the water on the blood vessels of the extremities. Both effects decrease TLC and VC. The TLC and VC were decreased for both the subjects and controls in this study, but it was not of statistical significance.

According to Pallot (1983), when the neuromuscular link between the control centers and the lungs is impaired, normal central drive results in a ventilation which is lower than normal although the lungs are unaffected. This phenomenon is caused by affected respiratory motor neurons in the cervical or thoracic spinal cord. A lower ventilation occurred for the paraplegics, but it was not significantly different.

In comparing the lung functions obtained in this study with Ruppel's (1982) typical values for men,
one can see that they are very close. Ruppel (1982) obtained a VC of 4.8, a RV of 1.2, FRC of 2.4, TLC of 6.0, and ERV of 1.2.

The "typical" person who weighs approximately 150 pounds and who is 5 ft. 9 inches tall has a percent body fat of approximately 15. All methods used on both the normals and the impaired in this study resulted in percents greater than that. This resulted, no doubt, from the fact that the average height of the subject was 5 ft. 7 inches with an average body weight of 196 pounds--distinctly above "normal" and indicating that both populations in this study were obese, if the impaired subjects in this study represent, faithfully, the impaired population. Thus, it is true that persons impaired by spinal cord injuries are obese because they have a percent body fat greater than the typical person, and because it was necessary to solicit for "normals" of the same height and weight, persons who were themselves obese.
Figure 2

D = DRY
W = WET

--- = controls
------- = subjects
DETERMINING PERCENT BODY FAT

COMPARISON OF THE METHODS

FIGURE 3

Skinfolds
J & P = Jackson & Pollack Generalized Equation
S = Sloan Equation

Circumferences
W&B = Wilmore and Behnke Equation
B = Behnke Equation

Underwater Weighing
L = RV done on Land
W = RV done in the Water
CHAPTER V

SUMMARY AND CONCLUSIONS

The need for data on body composition for the disabled is many-fold. Very few studies exist on this subject. Medically, the disabled can benefit from knowing their percent body fat to enable them to make transfers from a wheelchair easier and to be healthier for all aspects of daily living. Aesthetically, a thinner person is treated better in our society.

Conclusions

As a result of this study, it can be concluded that:

1. There were no differences in age, height or weight between normals and impaired.
2. Except with the two underwater weighing methods, there were no differences in estimated percent fat within each method between normals vs. impaired.
3. For the skinfold subtypes, the J & P equation gave a significantly smaller percentage of body fat than did the Sloan equation ($p < 0.025$).
4. For the circumference subtypes, the W & B equation gave a significantly smaller percent body fat than did the Behnke equation ($p < 0.01$).
5. With either method of underwater weighing, estimated percent body fat for the impaired was significantly greater than for the normals \((p<0.05)\).

6. There were no significant differences in percent body fat estimated by the "dry" or "wet" methods.

7. For underwater weighing, there were no significant differences in any of the parameters between normals and impaired. However, residual volume tended to be smaller in impaired vs. normal subjects \((0.1>p>0.05)\).

8. Both groups (impaired and non-impaired) were overweight when compared with a normal population of comparable height.
APPENDIX A

Advertisement Requesting Subjects
ANNOUNCEMENT FOR THE SCOREBOARD

- Take part in a $200 physical fitness assessment for free as part of a graduate students' study.

- Have 5 different methods of determining percent body fat calculated on you.

- Appointments can be set up for the evenings of May 11, 12, 14th at Dodd Hall on OSU's campus.

- Refer to the handouts in your packets for additional details.

- Call Carolyn at 614-292-5010 or Deb at 614-292-1038.

Ohio Wheelchair Games
BODY COMPOSITION STUDY

- Take part in a $200 physical fitness assessment for FREE as part of two graduate students' study.

- Have 5 different methods of determining percent body fat calculated on you! The results will be mailed to you one month later.

- Appointments can be set up for the evenings of May 11, 12, 14th at Dodd Hall, 472 W. 8th Ave., Columbus, Ohio 43210.

- Contribute to society and future generations, even though you are disabled.

QUALIFICATIONS

- Spinal-cord injured male paraplegics, ages 18 and over.

- Not taking any diuretics, hypertension medications or steroids.

SPECIFICATIONS

- No alcohol or caffeine for 24 hours before the testing.

- Nothing to eat or drink after 12 noon. Water is ok until 4:00 pm.

- Bring a swimsuit and sweatshirt or jacket.

- You will be there approximately 2 hours.

- A light meal will be served at the end of the session.

- The tests include: Skinfold calipers
  Underwater weighing
  Residual volume measurement of the lungs
  Circumference measurements
  Bio-electrical impedance

- You will be tested twice; two nights of the available three.

- As a subject, you have the right to privacy, confidentiality and to remain anonymous. Your name will not be released.

THANK YOU FOR YOUR HELP!!!

Please call:
Deb (w) 614-292-1038 or Carolyn (w) 614-292-5010
(h) 614-444-0764 (h) 614-846-6532
February 10, 1988

Dear

I would like you to consider being a participant in my dissertation research project.

Very little has been done on determining percent body fat in the disabled population. Knowledge gained form this study can aid in the establishment of reference values. This can benefit doctors, dieticians and improve a person's everyday life.

The benefits to you for being in the study include: finding out your percent body fat which will aid you in determining if you need a diet; excessive weight can lead to pressure sores and make transfers to and from the wheel chair more difficult. You can contribute to society even though you are disabled. Knowledge generated from this study will benefit future paraplegics.

Five tests, to determine percent body fat, will be compared to see which one is the most reliable for a disabled population. The tests include residual volume, the amount of air remaining in the lungs; underwater weighing; skinfold calipers; bioelectrical impedance, where a small amount of electrical current measures the amount of fat under the skin; and circumference measurements, where selected sites are measured with a tape measure.

As a subject in my study you have the right to privacy, confidentiality and to remain anonymous. You name will not be released.
Human subjects approval has been obtained with protocol number: 86H0152

The testing will take place on February 23, 24, 26, 27th. You need to pick two of the four sessions to attend. Each session will last two hours. Different time slots are available from 5:00-9:00 p.m. on the above dates. The testing will take place on the first floor of Dodd Hall, 472 West 8th Avenue.

It is necessary to not eat for 5 hours before the testing, to not have any alcoholic beverages for 24 hours before the testing or caffeine for 12 hours. A light meal will be served at the end of the testing session.

Please fill out the Subject Questionnaire and sign the human consent form. If you have any further questions, please do not hesitate to ask. You may withdraw from the study at any time.

Thank you for your help.

Sincerely,

Deborah L. Zechar,
Ph.D. candidate in Physical Education
APPENDIX B

Subject Participation Forms and Informed Consents
SUBJECT ASSESSMENT QUESTIONNAIRE

Name:____________________________ Date:______________________________

Date of birth;_________________ Age;_______ Race:_____________________

Address:________________________________________________________________________

Telephone (work and home):___________________________________________________________

1. Was your injury traumatically sustained? _______Yes _______No

2. What is your level of injury? _______ Complete or incomplete (circle)

3. What was your age at onset (month/year)? ______________________

4. Was the onset before puberty? _______ Yes _______No

5. What was your pre-injury height? ______________________

6. Do you use anabolic steroids? _______Yes _______No

7. If you have been confined to bed within the past 30 days, please indicate the dates: ______________________

8. Describe the severity of spasticity you have on a daily basis check one: Absent Mild Moderate Severe

9. Do you have any sensation in your lower extremities? _______Yes _______No

10. Are you or have you been involved in any intense physical exercise training programs? _______Yes _______No. If yes, please describe:


11. Please list the medications you are currently taking and the dosage:
12. Are you currently experiencing any respiratory ailments—
(cold, asthma, allergies, bronchitis, chronic cough, etc.)?
   _____Yes   _____No

13. Have you undergone any major surgical operations or been involved
    in a serious accident or illness in the past 3 months?
    _____Yes   _____No

14. Has your weight changed since the onset of your disability?
    _____Yes   _____No. Please describe: ___________________________________
CONSENT TO INVESTIGATIONAL TREATMENT OR PROCEDURE

1. I hereby authorize or direct Holly Lehnard, PhD, associate or assistants of his or her choosing, to perform the following treatment or procedure (describe in general terms). Four body composition assessments which include: hydrostatic (underwater) weighing and anthropometric measurements (skinfold thickness, body diameters, and circumferences, height, weight). Four bioelectrical impedance measurements and four of residual volume one single and dual photon absorptiometry. The experimental (research) portion of the treatment or procedure is: determining specific anthropometric measurements which will accurately predict body composition in nonambulatory individuals. This is done as part of an investigation entitled: Body Composition Assessment in Nonambulatory Individuals: Comparison to Ambulatory Individuals.

2. Purpose of the procedure or treatment: to measure body density from underwater weighing and bone mineral content in order to predict lean body and fat weight from these subjects. To determine specific anthropometric and bioelectrical impedance data that will correlate with the underwater weighing. To compare nonambulatory and ambulatory individuals on these parameters.

3. Possible appropriate alternative methods of treatment: Neutron activation, nuclear magnetic resonance.

4. Discomforts and risks reasonably to be expected: Risks are minimal. They include: Irritation of eyes and nose from being underwater, dull pinching from the skinfold callipers and exposure to very low levels of radiation from the photon absorptiometry. Minor skin irritation from adhesive on terminal electrodes of bioelectrical impedance machine, similar to irritation to tape adhesive.

5. Possible benefits for subject society: Establishment of initial procedures and techniques to determine body composition in nonambulatory persons. This will help in the dietary and nutritional recommendations for this population.

6. Anticipated duration of subject's participation: Four one-hour visits over a two-to-three week period.

I hereby acknowledge that ____________________________ has provided information about the procedure described above, about my rights as a subject, and have answered all questions to my satisfaction. I understand that I may contact him/her should I have additional questions. He/She has explained the risks described above and I understand them; he/she has also offered to explain all possible risks or complications.

I understand that, where appropriate, the U.S. Food and Drug Administration may inspect records pertaining to this study. I understand further that records obtained during my participation in this study may be made available to the sponsor of this study and that the records will not contain my name or other personal identifiers. Beyond this, I understand that my participation will remain confidential.
individuals on these parameters.

2. Possible appropriate alternative methods of treatment: Neutron activation, nuclear magnetic resonance

3. Discomforts and risks reasonably to be expected: Risks are minimal. The photon absorptiometry

   eyes and nose from being underwater, dull pinching from the skinfold calipers

   and exposure to very low levels of radiation from the photon absorptiometry.

   Minor skin irritation from adhesive on terminal electrodes of bioelectrical

   impedance machine, similar to irritation to tape adhesive.

4. Possible benefits for subjects/society: Establishment of initial procedures and techniques to
determine body composition in nonambulatory persons. This will help in the
dietary and nutritional recommendations for this population.

5. Anticipated duration of subject’s participation: Four one-hour visits over a two to three week
   period

I hereby acknowledge that ___________________________________________________________ has provided information about the procedure described above,
about my rights as a subject, and he/she answered all questions to my satisfaction. I understand that I may contact him/her
should I have additional questions. He/She has explained the risks described above and I understand them; he/she has also
offered to explain all possible risks or complications.

I understand that, where appropriate, the U.S. Food and Drug Administration may inspect records pertaining to this study.
I understand further that records obtained during my participation in this study may be made available to the sponsor of this study
and that the records will not contain my name or other personal identifiers. Beyond this, I understand that my participation
will remain confidential.

I understand that I am free to withdraw my consent and participation in this project at any time after notifying the project
director without prejudicing future care. No guarantee has been given to me concerning treatment or procedure.

In the unlikely event of injury resulting from participation in this study, I understand that immediate medical treatment is
available at University Hospital of The Ohio State University. I also understand that the costs of such treatment will be at my
expense and that financial compensation is not available. Questions about this should be directed to the Human Subject Review
Office at 622-1446.

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ______________________  Time: _______ AM Signed __________________________ (Subject)
Witness(es) ___________________________  (Person Authorized to Consent for Subject - If Required)
If Required __________________________

I certify that I have personally completed all blanks in this form and explained them to the subject or his/her representative
before requesting the subject or his/her representative to sign it.

Signed: __________________________
Informed Consent Form

Prior to testing the subjects and controls will have signed an informed consent from that will include:

1. That the value of the research is contributing to knowledge.

2. This research contributes to the development of technology.

3. The improvement of people's lives.

4. A description of the tests involved.

5. The right to privacy; you cannot release their name.

6. The right to remain anonymous.

7. The right to confidentiality.

8. Human subjects approval has been obtained.


10. A description of the benefits to be expected.

11. An offer to answer any inquiries concerning the procedures.

12. An instruction that the subject is free to withdraw consent and to discontinue participation in the project at any time.
APPENDIX C

Human Subjects Approval Form
February 17, 1987

Dr. Joseph F. Plouffe
Associate Professor of Medicine
N1135 Dean Hall
410 W. 10th Avenue
Columbus, Ohio 43210

Dear Dr. Plouffe:

This letter is written in regard to an addendum I wish to include in the protocol for "Assessment of Body Composition of Injured Spinal Cord Individuals", Protocol Number: 86H0152.

I would like to add Deborah Zechar as a co-investigator in this study. She is a Ph.D. student in Physical Education who will be assisting with the body composition measurements and determinations. Should you need further information, Deborah Zechar can be contacted at 292-1038.

Thank you for your time and consideration.

Sincerely,

Ernest W. Johnson, M.D.

xc: Sue Barker
Francis P. Lagattuta, M.D.
Deborah Zechar
THE OHIO STATE UNIVERSITY
BIOMEDICAL SCIENCES
HUMAN SUBJECTS REVIEW COMMITTEE

PRINCIPAL INVESTIGATOR: H. Richardson-Lehnard, PhD.
Academic Title: Assistant Professor - Physical Medicine
Typed Name: H. Richardson-Lehnard
Signature: 
Phone No. 421-3800

College: Medicine
Department: Physical Medicine

Campus Address: 471 Dodd Drive (Dodd Hall), Columbus, OH 43210

Co-Investigators:
Francis P. Lagattuta, M.D.  Typed Name: Francis P. Lagattuta, M.D.  Signature: Carolyn Wasson, B.S.  Deborah Zechar, B.A., M.S.

PROTOCOL TITLE: Assessment of Body Composition of Injured Spinal Cord Individuals

DEPARTMENT CHAIRPERSON'S ENDORSEMENT
Ernest W. Johnson, M.D.  Typed Name: Ernest W. Johnson, M.D.  Signature: 

PROPOSED PROJECT INVOLVES:

☐ New Drug (IND.) What is IND Number? _______ Issued to: __________
Generic name ________________________

☐ Investigational Device. What is IDE Number? _______ Issued to: __________

☐ Radioactive drugs or Unusual Exposure to External Radiation. Approval by the Medical Radiomucide Committee (Tel. 422-0122) is required for final approval by Human Subject Review Committee. Investigator is responsible for submitting to both committees.

☐ Pregnant Women - Approval by Maternal-Fetal Committee (Tel. 421-8736) is required for final approval by Human Subject Review Committee. Investigator is responsible for submitting to both committees.

THE PROPOSED ACTIVITY WOULD INVOLVE: (Check at least one.)

☐ Minors ☐ Pregnant Women ☐ Mentally Retarded
☐ Fetuses ☐ Prisoners ☐ Mentally Disabled
☐ Abortuses ☐ None of These

At least one reviewer of this protocol should be knowledgeable about the following disciplines (fields of science):  Physical Medicine
APPENDIX D

Sign-up Forms
SUBJECT SIGN-UP FORM

Monday Feb. 23rd:
1. 5:00_____________________________
2. 5:15_____________________________
3. 5:30_____________________________
4. 5:45_____________________________
5. 6:00_____________________________
6. 6:15_____________________________
7. 6:30_____________________________
8. 6:45_____________________________
9. 7:00_____________________________

Tuesday Feb. 24th:
1. 5:00_____________________________
2. 5:15_____________________________
3. 5:30_____________________________
4. 5:45_____________________________
5. 6:00_____________________________
6. 6:15_____________________________
7. 6:30_____________________________
8. 6:45_____________________________
9. 7:00_____________________________

Thursday Feb. 26th:
1. 5:00_____________________________
2. 5:15
3. 5:30
4. 5:45
5. 6:00
6. 6:15
7. 6:30
8. 6:45
9. 7:00

Friday Feb. 27th:
1. 5:00
2. 5:15
3. 5:30
4. 5:45
5. 6:00
6. 6:15
7. 6:30
8. 6:45
9. 7:00
Please help me with my dissertation testing! I need some volunteers to be recorders and spotters. Please sign up if you can help.

THANK YOU!! Deb Zechar

5:00 - 9:00 p.m. at Dodd Hall, 472 W. 8th. Avenue

Mon. Feb. 23rd:

1. __________________________
2. __________________________
3. __________________________
4. __________________________
5. __________________________
6. __________________________
7. __________________________

Tues. Feb. 24th:

1. __________________________
2. __________________________
3. __________________________
4. __________________________
5. __________________________
6. __________________________
7. __________________________

Thurs. Feb. 26th:

1. __________________________
2. __________________________
3. __________________________
4. __________________________
5. __________________________
6. __________________________
7. __________________________

Fri. Feb. 27th:

1. __________________________
2. __________________________
3. __________________________
4. __________________________
5. __________________________
6. __________________________
7. __________________________
APPENDIX E

Data Collection Sheets
<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Test</td>
</tr>
<tr>
<td>seated height</td>
<td>tilted height</td>
</tr>
<tr>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>______ mean</td>
<td>______</td>
</tr>
</tbody>
</table>

**Skinfolds:**

- triceps
- subscapular
- abdomen
- thigh
- chest

**Means:**

- Sloan
- Lohman
- Jackson & Pollock
CIRCUMFERENCES
1. Calf
2. waist
3. chest
4. biceps (flexed)
5. forearm (flexed)

Diameters
1. ankle
2. knee
3. elbow
4. wrist

Anthropometer
1. bitrochanter (top of leg)
2. bi-iliac (top of hip)
3. chest
4. biacromial (shirt seams)
5. shoulder
O.S.U. Work Physiology Laboratory

Hydrostatic Weighing Data Sheet.

Name:____________________________ Date:________ WT _________lbs.
Sex: M/F Age(yrs.)______ Ht.(IN.)________
Bar. Press. (corr.) ________ mm H20 temp. (C):_____ Density H20:____
Air temp. (C) ________ BTPS factor: 1.________
(from spirometer)

Vital Capacity (liters)

V1____ V2____ V3____ Mean of three highest volumes:____
V4_____ V5____ V6.____
Vital Capacity (BTPS) = mean volume x BTPS factor = VC______

Underwater Weight (kilograms)

W1____ W2____ W3____ W4____ W5____ Tare: ___________ kg.
W6____ W7____ W8____ W9____ W10____
Mean of last 3 weights:________ kg.
Weight in water (kg.): Mean Weight - tare weight * Ww________

Calculations

Weight in air (kg.): WT (lbs.) -- 2.2046 = Wa______
Residual Volume (males) = 0.24 x VC (BTPS) = RV______
(females) = 0.28 x VC (BTPS) = RV______

Results

% Body Fat = ___________ Lean body weight = _____lbs.
APPENDIX F

Results for subjects
Dear ______________________,

I am writing this letter to extend to you my heartfelt thanks for your time and trouble for participating in my study. I know how difficult it can be to schedule in activities such as this in an already hectic agenda. By your doing this, you are aiding mankind in the knowledge gained concerning body composition of spinal-cord injured people. It has also enabled us to move towards the completion of our graduate studies. Enclosed is a copy of your test results. Once again, thank you for your help.

Sincerely,

Deb Zechar
RESULTS FOR SUBJECTS

Body Composition Analysis

Name ____________________________  Date ________________________

Body Weight ______________ lbs.  =  ______________ Ags.

Vital Capacity ______________ L (BTPS)

Percent Body Fat  ______________  %  Technician ____________________

This means that __________ lbs. of your weight is fat, and
that __________ lbs. are lean tissue (muscle, bone, etc.).

The following are calculations of what your body weight would be at
other body fat percentages (assuming that your body density does not
change):

<table>
<thead>
<tr>
<th>% Body Fat</th>
<th>Body Wt. (lbs.)</th>
<th>% Body Fat</th>
<th>Body Wt. (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The most effective and safest method of weight loss involves proper diet
and aerobic exercise. Medical advice may be prudent prior to undertaking
such a program.

Further physiological testing and counseling in physical fitness and
nutrition are available from the O.S.U. Physical Education Department.
APPENDIX G

Subjects' and Controls' Raw Data
<table>
<thead>
<tr>
<th></th>
<th>Age-S</th>
<th>Age-C</th>
<th>Height-S</th>
<th>Height-C</th>
<th>Weight-S</th>
<th>Weight-C</th>
<th>Race</th>
<th>Yrs. Injured-S</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>49</td>
<td>42</td>
<td>5'6&quot;</td>
<td>5'8&quot;</td>
<td>140</td>
<td>152</td>
<td>white</td>
<td>30</td>
</tr>
<tr>
<td>2.</td>
<td>52</td>
<td>53</td>
<td>5'8&quot;</td>
<td>5'6&quot;</td>
<td>227</td>
<td>189</td>
<td>black</td>
<td>17</td>
</tr>
<tr>
<td>3.</td>
<td>26</td>
<td>19</td>
<td>5'7&quot;</td>
<td>5'9&quot;</td>
<td>248</td>
<td>215</td>
<td>white</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>28</td>
<td>23</td>
<td>5'8&quot;</td>
<td>5'7&quot;</td>
<td>145</td>
<td>154</td>
<td>white</td>
<td>6</td>
</tr>
<tr>
<td>5.</td>
<td>27</td>
<td>27</td>
<td>5'10&quot;</td>
<td>6'0&quot;</td>
<td>231</td>
<td>225</td>
<td>black</td>
<td>11</td>
</tr>
<tr>
<td>6.</td>
<td>44</td>
<td>33</td>
<td>5'2&quot;</td>
<td>5'6&quot;</td>
<td>186</td>
<td>189</td>
<td>white</td>
<td>5</td>
</tr>
<tr>
<td>7.</td>
<td>32</td>
<td>34</td>
<td>5'10&quot;</td>
<td>5'11&quot;</td>
<td>181</td>
<td>183</td>
<td>white</td>
<td>13</td>
</tr>
<tr>
<td>8.</td>
<td>37</td>
<td>40</td>
<td>5'5&quot;</td>
<td>5'10&quot;</td>
<td>209</td>
<td>245</td>
<td>white</td>
<td>18</td>
</tr>
<tr>
<td>X</td>
<td>37</td>
<td>34</td>
<td>5'7&quot;</td>
<td>5'9&quot;</td>
<td>196</td>
<td>194</td>
<td></td>
<td>13</td>
</tr>
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</table>

S = Subjects  
C = Controls
Level of Injury (Subjects)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Vertebrae</th>
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<tbody>
<tr>
<td>S-1</td>
<td>T-7</td>
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<td>T-8</td>
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<td>T-10</td>
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<tr>
<td>S-8</td>
<td>T-4</td>
</tr>
</tbody>
</table>

\[ \bar{X} \quad T-7 \]
LATERAL VIEW OF THE SPINE

Figure 4
Subjects' Percent Fat by the Skinfold Method on Two Different Days by Two Different Equations

<table>
<thead>
<tr>
<th>Subject</th>
<th>Jackson &amp; Pollock</th>
<th>Sloan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>S-1</td>
<td>12.90</td>
<td>12.90</td>
</tr>
<tr>
<td>S-2</td>
<td>21.03</td>
<td>21.03</td>
</tr>
<tr>
<td>S-3</td>
<td>21.04</td>
<td>25.22</td>
</tr>
<tr>
<td>S-4</td>
<td>8.95</td>
<td>8.95</td>
</tr>
<tr>
<td>S-5</td>
<td>16.90</td>
<td>16.90</td>
</tr>
<tr>
<td>S-6</td>
<td>25.22</td>
<td>----</td>
</tr>
<tr>
<td>S-7</td>
<td>16.90</td>
<td>16.90</td>
</tr>
<tr>
<td>S-8</td>
<td>33.80</td>
<td>29.50</td>
</tr>
</tbody>
</table>

$\bar{X}$ 19.6 19.6 23.6 25.2
### Controls' Percent Fat by the Skinfold Method on Two Different Days by Two Different Equations

<table>
<thead>
<tr>
<th>Controls</th>
<th>Jackson &amp; Pollock</th>
<th>Sloan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>C-1</td>
<td>16.90</td>
<td>16.90</td>
</tr>
<tr>
<td>C-2</td>
<td>25.22</td>
<td>25.22</td>
</tr>
<tr>
<td>C-3</td>
<td>16.93</td>
<td>16.93</td>
</tr>
<tr>
<td>C-4</td>
<td>5.07</td>
<td>5.07</td>
</tr>
<tr>
<td>C-5</td>
<td>16.90</td>
<td>16.90</td>
</tr>
<tr>
<td>C-6</td>
<td>25.22</td>
<td>25.22</td>
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<td>C-7</td>
<td>8.95</td>
<td>8.95</td>
</tr>
<tr>
<td>C-8</td>
<td>25.22</td>
<td>25.22</td>
</tr>
</tbody>
</table>

| X        | 17.6    | 17.6    | 22.8    | 22.3    |
Subjects' Percent Fat by Circumferences on Two Different Days by Two Different Equations

<table>
<thead>
<tr>
<th>Subject</th>
<th>Wilmore &amp; Behnke</th>
<th>Behnke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>S-1</td>
<td>19.52</td>
<td>19.64</td>
</tr>
<tr>
<td>S-2</td>
<td>19.37</td>
<td>18.63</td>
</tr>
<tr>
<td>S-3</td>
<td>22.17</td>
<td>21.45</td>
</tr>
<tr>
<td>S-4</td>
<td>3.74</td>
<td>2.64</td>
</tr>
<tr>
<td>S-5</td>
<td>24.59</td>
<td>23.66</td>
</tr>
<tr>
<td>S-6</td>
<td>22.64</td>
<td>------</td>
</tr>
<tr>
<td>S-7</td>
<td>21.58</td>
<td>20.49</td>
</tr>
<tr>
<td>S-8</td>
<td>31.55</td>
<td>35.08</td>
</tr>
</tbody>
</table>

| X       | 20.6   | 20.5   | 30.8   | 30.4   |
Controls' Percent Fat by Circumferences on Two Different Days by Two Different Equations

<table>
<thead>
<tr>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
</tr>
<tr>
<td>C-2</td>
</tr>
<tr>
<td>C-3</td>
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<td>C-4</td>
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<td>C-5</td>
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<tr>
<td>C-7</td>
</tr>
<tr>
<td>C-8</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Wilmore &amp; Behnke</th>
<th>Behnke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>C-1</td>
<td>13.98</td>
<td>11.80</td>
</tr>
<tr>
<td>C-2</td>
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<td>27.95</td>
</tr>
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<td>C-3</td>
<td>16.97</td>
<td>17.53</td>
</tr>
<tr>
<td>C-4</td>
<td>10.50</td>
<td>10.77</td>
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<td>C-5</td>
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<tr>
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<td>22.74</td>
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</table>

X: 16.1  16.6  27.2  27.4
Subjects' Percent Fat by Underwater Weighing Using Actual RV on Land on Two Different Days

<table>
<thead>
<tr>
<th>Subject</th>
<th>Goldman &amp; Buskirk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>S-1</td>
<td>47.48</td>
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<tr>
<td>S-2</td>
<td>35.29</td>
</tr>
<tr>
<td>S-3</td>
<td>40.09</td>
</tr>
<tr>
<td>S-4</td>
<td>21.43</td>
</tr>
<tr>
<td>S-5</td>
<td>40.09</td>
</tr>
<tr>
<td>S-6</td>
<td>30.58</td>
</tr>
<tr>
<td>S-7</td>
<td>35.29</td>
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<tr>
<td>S-8</td>
<td>50.00</td>
</tr>
<tr>
<td>( \bar{X} )</td>
<td>37.5</td>
</tr>
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</table>
Controls' Percent Fat by Underwater Weighing Using Actual RV on Land on Two Different Days

<table>
<thead>
<tr>
<th>Control</th>
<th>Goldman &amp; Buskirk</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>C-1</td>
<td>23.23</td>
</tr>
<tr>
<td>C-2</td>
<td>30.58</td>
</tr>
<tr>
<td>C-3</td>
<td>21.43</td>
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<td>C-7</td>
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</tr>
<tr>
<td>C-8</td>
<td>37.68</td>
</tr>
</tbody>
</table>

\[ \bar{X} \quad 23.8 \quad 24.4 \]
Subjects' Percent Fat by Underwater Weighing Using Actual RV in the Water on Two Different Days

<table>
<thead>
<tr>
<th>Subject</th>
<th>Goldman &amp; Buskirk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>S-1</td>
<td>45.00</td>
</tr>
<tr>
<td>S-2</td>
<td>35.29</td>
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<td>S-4</td>
<td>25.96</td>
</tr>
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<td>S-5</td>
<td>40.09</td>
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<td>S-7</td>
<td>35.29</td>
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<tr>
<td>S-8</td>
<td>50.00</td>
</tr>
</tbody>
</table>

\[ \bar{X} = 38.4 \quad 38.4 \]
Controls' Percent Fat by Underwater Weighing Using Actual RV in the Water on Two Different Days

<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>C-1</td>
<td>25.96</td>
<td>30.58</td>
</tr>
<tr>
<td>C-2</td>
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<td>35.29</td>
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\[ \bar{X} = 23.3 \quad 24.2 \]
Subjects' Lung Function Measurements Under Two Different Conditions

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Controls' Lung Function Measurements Under Two Different Conditions

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|         | wet       | 4.67| 1.53| 2.02| 6.14 | 0.55 |
### Subjects' Circumference and Diameter Measurements

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L = left
R = right*
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C = control  
L = left  
R = right
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<tr>
<td><strong>Method 2 (Circumference)</strong></td>
<td>880.32</td>
<td>1</td>
<td>32.52</td>
<td>.01</td>
<td></td>
<td>-5.70 &lt; .01</td>
</tr>
<tr>
<td><strong>Method 3 (Underwater Weighing)</strong></td>
<td>.845</td>
<td>1</td>
<td>.08</td>
<td>.25</td>
<td></td>
<td>-1.79 &gt; .25</td>
</tr>
</tbody>
</table>

- Skinfold Type 1 = Jackson & Pollack Generalized Equation
  - Type 2 = Sloan Equation
- Circumference Type 1 = Wilmore & Behnke Equation
  - Type 2 = Behnke Equation
- Underwater Weighing Type 1 = Dry conditions
  - Type 2 = Wet conditions


