THE RELATIVE ACCURACY OF FOUR SKINFOLD ESTIMATION METHODS IN PREDICTING THE PERCENT BODY FAT OF COLLEGE MALES

by

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Chapter 1

INTRODUCTION

Within the past ten years there has been a promising resurgance of interest in physical exercise and fitness. A 1977 Gallup Poll found that nearly half of the American Adults indicated they exercise regularly to keep fit (24, 55). With this concern in fitness has also come increased knowledge and concern about weight control.

Renewed interest in exercise has brought on the need for assessing selected health and fitness parameters in which body composition is one of the five major health fitness components (20). These five aspects of health related fitness include: (1) cardiovascular endurance, (2) muscular endurance, (3) muscular strength, (4) flexibility, and (5) body composition. Body composition refers to the relative amount of bone, muscle and fat in the body. Fluctuations in weight are most often attributed to changes in fat; however, one may be overweight according to a standard on the basis of either his or her bone structure or musculature and yet not be obese or excessively fat. It is also true that an individual may be of average weight and yet be excessively fat if he or she has a relatively small musculature or bony structure (33). Thus body weight can be deceiving if it is used to predict total body fat. This also indicates that the terms "overweight" and "overfat" do not refer to the same condition, and that height and weight tables cannot be used to determine overfatness. Thus, the percent of total body fat is far more relevant as a factor in body compostion changes than body weight.

Fat, not weight, is the problem in this country. It is not how heavy a person becomes that has significance, but rather how much fat he carries and how much fat he adds (34). Obesity refers to a high degree of fatness in the body and occurs when the body stores excess calories (primarily in the adipose tissue) that were not burned off. This excess gradually builds until the individual has stored a large amount of unneeded fat. The recommended level of fat for adults is around 16% for males and 20-23% body fat for females (38). If a male exceeds 25% and a female exceeds 30% they are usually considered obese (24, 38). Unfortunately, being overfat is a condition shared by about one-fourth of the population in the United States (20, 49).

Obesity is one of the most prevalent health problems in the United States today (24). It has been regarded as an abnormal condition by most physicians and laymen. Although the nature of the relationship between obesity and certain diseases is not clear, the higher mortality rate experienced by obese persons makes it a major helath problem (32). Excess accumulation of body fat is undesirable from a health standpoint. Obesity has been shown to correlate highly with coronary heart disease, high blood pressure, gallblatter disease, and diabetes (20, 24, 27, 49). Since obesity correlates highly with coronary heart disease it is considered to be one of the major risk factors for that medical problem.

Excess body fat has also been shown to have detrimental effects on motor performance (56, 64). Whether the individual is an athlete or a sports enthusiast, "overfat" can lead to a hindrance of performance. Two examples of the detrimental effects of excess fat are that fat cells do not contribute toward energy production and high fat content costs more energy to move (56).

The best method to predict the amount of fat that an individual contains is to determine body density. Hydrostatic weighing, radiographic analysis, potassium K-40, and total body water determination are laboratory methods used to measure body density. These methods are valid but not practical for

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mass or field testing because of time, cost of equipment, and complex procedures. The problems presented by these methods created the need for simple and rapid procedures which would estimate body density and percent of fat with a reasonable amount of accuracy.

Anthropometry is by far the most extensively used non-laboratory method. Anthropometric methods include the measurement of skinfold thicknesses, circumferences, and diameters of the various body segments. Anthropometric measurements have been used extensively, require little or no area and equipment, and the measures can be easily and quickly obtained.

As stated earlier, the renewed interest in exercise has increased the need for assessing fitness levels of all adults, including young adults. College students, who exercise for their health and also the high school or college athlete needs to determine their relative strengths and weaknesses in relation to various fitness elements. Test items providing this information must; (1) be feasible for testing large groups of individuals, (2) provide a basis of prescription for the new participant and (3) detect the changing status of the experienced fitness enthusiast. Anthropometric methods have been demonstrated to meet all of these criteria (7).

Equations to predict percent body fat have been developed that include one or more of the anthropometric measures. Results from these equations have been validated against the findings of underwater weighing and found to be very reliable (27, 32). However, these equations are population specific in that they cannot be effectively applied to different types of individuals from those in the original studies. A major problem is determining which equation(s) is most accurate for the population to which the equation will be applied. Equations are limited by age and sex. Many equations involving various

anthropometric measurements have been done. Skinfold thicknesses at various sites have been found to be a very good measure of subcutaneous fat by numerous investigations (7, 12, 13, 27, 29, 32, 43).

Four equations for estimating body density from skinfold measures alone were examined. The equations involve a combination of different skinfold sites. All four equations were formulated for college age males. With the increased need to find the most accurate skinfold equation for fitness enthusiasts and athletes, four equations (two that have been used extensively in the last 30 years, and two others that were recently developed) were evaluated to find which equation most accurately and consistently predicted percent body fat. The first equation was developed by Pollock et al (65) and uses the subscapula, chest and thigh measurements. The second equation considered in this study was the result of work by Brozek and Keys (13) and involves the use of the tricep, abdomen, and pectoral skinfolds. The final two equations examined were developed for the YMCA. None of the work related to the development and use of these tests have been published. The first method, YMCA #1, uses six sites (subscapula, tricep, pectoral, illiac, abdomen, and thigh), while the second (YMCA #2) uses four sites (axilla, pectoral, illiac, and abdomen). The main differences between the four equations are the number of sites plus the relative weights of each site.

STATEMENT OF PROBLEM

As the interest in fitness testing rises it becomes necessary to determine a valid skinfold equation for use in the estimation of percent body fat in college age males.

PURPOSE OF STUDY

It was the purpose of this study to compare the accuracy of four skinfold estimation techniques in predicting percent body fat of young adult males as estimated by hydrostatic weighing.

LIMITATIONS

Certain factors which may have limited this study should be noted:

1. Skinfold equations were validated against the density values obtained by underwater weighing. This value was assumed to be a valid estimate of body composition.

2. Estimation of functional residual capacity by the method of helium dilution is assumed to be accurate measurement.

3. The helium analyzer was found to be malfunctioning at a constant rate so a correction was used. This was assumed to correct the problem.

DELIMITATIONS

Generalizations from the results of this study are restricted because of the following factors:

1. This study was delimited to 50 volunteer male students enrolled at Kansas State University during the spring semester 1980.

2. This study was limited to only four estimation techniques for body density for the population of 18-22 year old males.

DEFINITIONS

The following list of terms needs to be understood to comprehend the main ideas presented in this paper.

Body Density

The density of the body is equal to the body mass (weight) divided by the body volume.

Body Volume

This is the actual volume of the body not including the space taken up by the lungs.

Fat Free Weight (FFW)

Fat free weight is the body weight of the individual with all fat removed.

Functional Residual Volume

This is the volume of gas remaining in the lungs at the end of a quiet exhalation; it is composed of the expiratory reserve and the residual volume.

Land Weight

The subjects' weight was taken in a nylon swimsuit, in a state of normal hydration, after an hour fast.

Lean Body Weight

This is the same as (FFW). Weight of the body free of all fat.

Obese

Obese is the state of having a high degree of body weight as fat. Twenty-five percent or more for the adult male is considered overfat.

Relative Body Weight

This is the proportion of fat tissue in the body often expressed as a percentage of body weight (percent body fat).

Residual Volume

This is the volume of air remaining in the lungs and associated airways following a maximum expiration. This term, when used in conjunction with underwater weighing, refers to the air remaining in the lungs and airways during the underwater weighing.

Total Body Fat (TBF)

The total body fat of the individual is the lean body weight subtracted from the land weight.

Underwater Weight

This is the weight of the body when it is totally immersed. This weight is corrected for residual volume lift.

Chapter 2

REVIEW OF THE LITERATURE

This chapter presents a review of pertinent literature related to various estimates of body composition. Literature reviewed pertains to: (1) laboratory methods, (2) underwater weighing as a means of determining body density, (3) the measurement of residual lung volume, and (4) field techniques (such as anthropometry, somatotyping, and height-weight tables).

LABORATORY METHODS FOR ASSESSING BODY COMPOSITION

The human body is made up of two types of tissue, fat and lean. The amount of fat tissue in the body is the major area of concern and is expressed as a percentage of the body's total weight. A percentage of over 25% in the male constitutes obesity (49). Lean body tissue is composed of bone and muscle mass found in the body. Once you know the value of one of the components you can then calculate the unknown value. Accurate assessment of body fat and lean body weight has been measured by both direct and indirect methods. This section will review several of the laboratory techniques used in the measurement of body composition.

Cadaver Analysis

The only means to directly measure the composition of the human body is by dissection and chemical analysis of cadavers. This method consists of the mechanical separation and weighing of the fat in adipose tissue or of the solvent extraction of the body. Numerous investigators have used this technique or reviewed the data presented over the years

(7, 33, 49, 53, 54, 62, 77). The major problems include the difficulty in obtaining good specimens. The efforts involved are enormous and the resulting data are questionable with respect to the generality of their applicability (7, 53, 54). The use of cadavers from a small sample cannot be expected to generalize for a total population.

More extensive work on animals has been done but it is unknown if the resulting data matches comparable data on humans. (7, 49, 54). Consequently, the majority of research on body composition of humans has been conducted through indirect methods usually being validated against widely accepted indirect methodology (7).

Biochemical Techniques

A number of biochemical approaches exist for determining the basic fat and lean components of the body. These vary considerably in complexity and validity but each technique makes a unique and valuable contribution to the gaining of a better understanding of the basic composition of the body. A summary of these methods follows.

Total body water. The biological "constant" for water in the lean body tissue has been established as 73.2% (7). Thus it is possible to estimate lean body weight from a measurement of total body water. In a normally nourished person 10-30 percent of water is found in adipose tissue (77). If total body water is known, the amount of body fat can be determined. Total body water can be measured through one of several techniques of isotopic dilution (7, 12, 37, 59, 70, 77). The tracers most commonly used include antipyrine, deuterium oxide, and tritium oxide. The typical procedure for any one of these tracers includes either an oral injestion or the injection of a specified quantity of the tracer into the venous blood; an equilibrium period, and a sampling period. The technique is based on the assumption that there is a uniform distribution of the tracer throughout the body fluids. Sampling to see how much of the tracer element is present is done from the blood or urine. Most studies have been done on animals and showed a high correlation with specific gravity, body density, and direct biochemical techniques (12).

Electrolytes and K-40. The application of electrolytes to the measurement of body composition has resulted in important advances in the understanding of anatomical complexities (37, 59). Sodium (Na^t), potassium (K+), and chlorine (Cl+) are the electrolytes that have been used in measurement. These electrolytes occur naturally in the body's lean tissue. A known amount of one of the electrolytes is consumed and after a 24 hour equilibrium period the difference in the urine is noted. Investigators have determined the total amounts of each electrolyte for the normal adult (7, 11, 37, 59, 62).

The body emits naturally occurring gamma radiation in the form of K-40. Since K-40 does represent proportionally the total potassium content and since the lean body tissue has a fairly constant potassium content and constitutes the primary source of potassium, the ability to measure K-40 is of great practical significance relative to body composition assessment (7). Measurement of the K-40 is assessed by radioactive counting (11, 59, 62).

Creatinine Excretion. It is widely believed that the amount of creatinine excreted in the urine is somehow related to the amount of muscle in the body. The creatinine coefficient is calculated as a ratio of the 24 hour excretion of creatinine in mg to body weight in kg as an accurate indication of lean body weight (12). Creatinine measurement has been used most often by nutritionists (83). Creatinine measurement has provided nutritionists with a measurement of body fat in counseling individuals on weight loss programs.

Soft Tissue X-Ray

Soft tissue x-rays have been useful in the assessment of body composition. X-rays have been shown to differentiate between the various layers of skin, fat, bone and muscle (7, 8). The fat is not compressed during measurement and x-rays can measure the fat pads that are difficult to measure (33). Through the use of x-rays, fat can be measured at an individual site or an estimation of total fat can be determined through the use of regression equations.

Garn (34-37) was one of the first to use x-rays and he devoted systematic attention to the methods of x-ray as a tool for the analysis of body composition and body build with special reference to fat patterning. The best sites found on the male were near suitable bony landmarks such as the mid-trochanteric, illiac, or lower thoracic (12, 14, 16, 34-37, 75).

Ultrasound

Because muscle, bone and fat have different densities and acoustical properties it is possible to use high frequency sounds to differentiate between tissue types. The thickness and density of the tissue through which the ultrasonic waves pass determine the characteristics of the reflected sound waves (7). The majority of work using ultrasound to assess body composition has been performed on animals. Sloan (72) has reported a relatively high correlation (r= 0.81) between body density as determined by hydrostatic weighing and a regression equation estimate of density based on several ultrasonic measurements.

UNDERWATER WEIGHING

Underwater weighing is the most widely used laboratory method for determining body composition (4, 7, 15, 17, 25, 39, 40). This method utilizes Archimedes' basic physical principle that a body immersed in a fluid is acted on by a buoyancy force, made evident by a loss of weight equal to the weight of the displaced fluid (7). Because of this, principle investigators have been able to determine the density of any object through the relationship of weight to volume (density = weight/volume).

With the body divided into two major components when considering body composition - lean tissue and fat tissue - it is possible to estimate the body fat and lean body weight from the calculated body density. The lean mass and fat have constant, but different densities. Early investigations established an inverse relationship between the fat content and body density (7, 69). The density of fat is a variable depending on parameters of age and sex (4, 11). It therefore has been proposed to use the density of ether extracted fat (.900) at 36 C, a value less subject to fluctuation. Densitometry assumes that the lower the density the higher the fat content of the body will be (11, 26, 65).

Early work in underwater weighing was done by Stern and Spicak (39) but the data was inconclusive because they failed to measure for residual volume. Behnke and his colleagues were first to determine body density and compensate for the air remaining in the lungs at the time of underwater weighing (7).

Rathburn and Pace (66), Brozek et al (9), and Siri (70) have derived basic equations for estimating relative body fat which are very similar, differing only in that different values were used to estimate the densities of the fat and lean tissue components.

Equations: Rathburn and Pace

$$\text{Fat \%} = \left(\frac{5.548}{\text{Density}} - 5.044\right)100$$

Brozek et al

$$\text{Fat \%} = \left(\frac{4.570}{\text{Density}} - 4.142\right)100$$

Siri

$$\text{Fat \%} = \left(\frac{4.950}{\text{Density}} - 4.500\right)100$$

Rathburn and Pace (66) formulated a quantitative relationship between body density and fat deposits in guinea pigs by comparison with direct chemical analysis. These were then derived for humans and were related to body specific gravity rather than density. This equation is widely used but contains an error because of the incorrect value used for fat density. A value of .918 for fat was used whereas the other two equations used .90 as the value of fat density.

Brozek separated body weight into its fat (d=0.9007) and fat free (d=1.100) fractions. The men used were matched for height but different in density. They felt this was a stable chronic "static" condition. The resulting formula was applicable to the estimation of the fat content in individuals in whom the body weight has been free from large, recent fluctuations.

Siri looked at men as a fat free body and assumed that all normal humans are identical in their ratios of water, protein and mineral, and that man differs only in possessing varying proportions of pure fat. Siri found the density of pure fat to be .90 gm/cc and LBM to equal 1.1 gm/cc.

These equations result in similar values for calculated relative fat. This is illustrated by the correlations of .995 and .997 which was found in a sample of 54 college males (81).

A study of the replicability of density determinations by Durnin and Taylor made on 10 young men on two - five occasions one day apart, indicated that with the given procedures for measuring body weight and volume the standard error of a single observation was 0.0023 units of density.

Keys and Brozek (53) measured the density of 35 trained subjects on two seperate occasions, with one week separating the measures. The reliability coefficient was r = .95. This gave a good indication of the ability of underwater weighing to accurately reproduce density.

A source of error that is inherent in body density determinations is that two extraneous volumes are included in total body volume. A correction must be made for the air remaining in the lungs, the residual volume, at the time of underwater weighing. The residual volume makes a sizeable contribution in the estimate of the total body volume and since it is highly variable it is essential to obtain a close approximation of the individual's actual residual volume. The second volume, air in the gastrointestinal tract (GI) is of considerably smaller magnitude and is seldom measured. Buskirk (17) has proposed the use of a constant correction of 100 ml., to approximate the air volume of the GI tract.

RESIDUAL VOLUME

Archimedes principle for the measurement of density is convenient but in the case of the living human it is necessary to correct for the air in the lungs at the time of underwater weighing (10). This air remaining in the lungs exerts a buoyant force on the body, making the body appear less dense, and therefore containing more fat than the person actually carries.

Residual volume, 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; therefore the residual volume must be determined by indirect methods. Three types of indirect methods are normally classified for residual volume determinations; (1) the pneumatometric approach, (2) closed circuit approach, and (3) open circuit method.

The open and closed circuit methods are the two techniques normally used. The pneumatometric method has been articized by Christie (19) and is seldom used. The pneumatometric method is a technique in which the relationship among ambient air pressure, temperature, volume, water vapor, and mass is utilized to estimate body volume of the subject.

Both the open and closed circuit methods provide a valid and reliable estimate of residual volume but have the common limitation of requiring considerable time to complete a single determination for one subject (57, 60).

The open circuit method consists of a nitrogen "washout". This involves the subject breathing a known quantity of pure oxygen. When complete mixing of the oxygen and nitrogen in the lungs has take place the volumes are analyzed and residual volume computed.

Closed circuit approaches involve a dilution and eventual equilibrium of a tracer, or indicator, gas such as nitrogen, hydrogen or helium. The nitrogen and helium dilution methods are the most commonly used methods, (21, 27, 28, 40, 43, 74, 78, 84). Willmon and Behnke were the first to employ helium or nitrogen washout techniques.

Because of the large time required to measure residual volume of these methods many investigators have used estimated values for residual volume in the calculation of body density. Of course, the major source of error usually occurs as a result of the subject not exhaling to the same residual volume. This may lead to errors in body volume as large as $\pm$ 500 ml for a given individual (7, 17). Numerous investigators feel that to determine body density accurately the residual volume must be determined at the time of underwater weighing (17, 22, 40, 57).

The three to four breath oxygen rebreathing method (21, 40) and the seven minute nitrogen washout method (28, 60) have shown success when used with underwater weighing. These two methods are used simultaneously with underwater weighing and the main difference between the two is the length of time the subject breathes oxygen through the delivery line. Both methods check the nitrogen content in the system to measure residual volume. The seven minute nitrogen washout takes a longer amount of oxygen to reach the nitrogen left. Two other commonly used determinations of residual volume are Meneely's (57) closed circuit helium dilution technique and the closed circuit nitrogen washout technique as described by Buskirk (17). Meneely's helium dilution technique is very similar to the technique used during this study.

FIELD TECHNIQUES FOR ESTIMATION OF BODY COMPOSITION

The ability to accurately assess body fat and lean body weight in humans has been successfully achieved through a variety of methods, each based on a set of principles unique to that specific method. The most common and precise methods currently used are laboratory methods prescribed in earlier sections of this chapter. Although these methods are accepted as accurate and reliable, they all share common problems of requiring: (1) considerable time for a single determination, (2) relatively elaborate and expensive equipment, and (3) rather complex procedures (80).

Other techniques more applicable to mass testing and use in a non-laboratory setting have been developed in recognition of these problems. These techniques include anthropometric techniques of caliper measurement of skinfold thickness, circumferences and diameters. Other field techniques include somatotyping and the use of height-weight tables.

Before looking at some of the other more scientific field techniques for measuring body fat it is appropriate to look at a couple of simple body fat determinations that have been included in the literature (31, 36, 83). These techniques are very simple and do not require any equipment or special training.

By use of a mirror one can take a realistic appraisal of the body. The nude body is often a more reliable guide for estimating obesity than body weight. Also there is the "pinch test". At least half of fat in the body in young adults is found directly under the skin (33). At many locations on the body (for example the tricep, and abdomen) a fold of skin and subcutaneous fat can be lifted. An individual should be able to lift ½ inch - 1 inch of skin. If the fold is greater than one inch it may indicate excessive body fatness. Several measures can be taken to tell whether the first was characteristic of the whole body. One last method discussed is circumference of the chest at the nipples and at the abdomen at the level of the navel. The circumference of the chest should exceed the abdomen by a few inches in men. When the abdominal girth approaches, equals, or exceeds the chest, excess fat is indicated. These measurements are fine as gross indicators but most individuals are interested in a numerical value of their percent of body fat (83).

Height-Weight Tables

Over the last fifty years height-weight tables have been used extensively to determine ideal weight. One of the best known norms has been the Metropolitan Life Insurance Table (33). Fox (33) states that a comparison of actual weight to either average or desireable weight standards gives an estimate of degree of overweight or underweight but does not give an accurate index of fatness or of body composition. These tables are based on the concept that once growth in height has ceased, there is no biological need to gain weight and that the best prognosis is found in individuals of average weight in their twenties.

Brozek and Keys (12) reported a definite relationship between body weight and fat but found that it was not possible to make a reliable prediction of obesity from body height and weight. These tables (based on age, sex, and height) do not take into consideration the bony structure, musculature and the distribution of fat of an individual (8, 11, 33, 69). Several investigators felt that the assessment of body on the basis of height and weight standards is an inadequate and unsound determination (2, 23, 27, 29, 49, 83), even those which attempt to account for variations in frame size (81, 83).

Despite the limitations noted height and weight tables are still the most commonly used criterion of being overfat. These tables are meant only as a general guide of fatness (2).

Somatotyping

Somatotyping is a method which assesses both bone structure and body build (7, 8). This procedure was developed by Sheldon (8) and involves photographs of a near nude body form three views (front, rear, side). Somatotyping is employed to components on a seven-point scale. These components of physique include: endomorph, mesomorph, and ectomorph. Endomorphs are characterized by their roundness and softness. Ectomorphs are usually tall and slim, while mesomorphs are usually characterized as the athletic look of muscularity (38).

From the use of photographs the individuals are given a rating of one (minimum) to seven (maximum) depending on the category that they fall into. This technique is not easily adapted to mass populations or office practices. Its reproducibility depends on the application by experts for grading and interpretation (7, 8, 33, 40, 61).

Anthropometric Methods

Anthropometry involves the measurement of skinfold thicknesses, circumferences and diameters. These measures are used singularly or in combinations in the form of regression equations to predict body density, which is then changed to percent body fat. Equipment used in anthropometry includes skinfold calipers, anthropometers and cloth measuring tapes.

The ability to predict accurately the relative leanness-fatness of males and females of different ages through the use of various anthropometric variables has been demonstrated repeatedly (3, 5, 7, 13, 32, 41). Studies have shown the validity of using skinfolds or a combination of circumferences and skinfold thicknesses to predict body composition parameters to vary from .65 to .87 for the prediction of body density and specific gravity and from .90 to .98 for prediction of body fat and lean body weight (13, 27, 63, 73, 81). These anthropometric variables have been shown to vary with age, sex and physical activity.

The diameters of the body can be measured rather accurately and with a high degree of reliability because of the nature of the measurement. In almost all instances the measurements are made with a bone to bone contact. This greatly reduces the range of variability within a subject and facilitates accurate measurements (7).

Circumferences are another alternative procedure developed to measure body density. The girths or circumferences are measured using a cloth tape at selected sites. Applying the tape lightly to the skin surface so it is taut but not tight obtaining the most accurate measure (7, 49).

Wilmore and Behnke (7), in an unpublished study, took a comprehensive series of anthropometric measurements on 54 college age males. Using anthropometric data they found a correlation r = .98 between actual and predicted weight. They found that when using the formula $W = (c/k)^2 \times h\ 0.7 \times .263$ (where c is equal to the sum of eleven circumferences, k = 300, and h is height) the actual weight and scale weight correlated very strongly.

Wilmore and Behnke (81) also evaluated the predictability of body density and lean body weight on a sample of 133 college age males using 54 anthropometric measurements of skinfolds, diameters and girths. Using underwater weighing as the criterion they found correlations ranging from .792 to .958. The results indicated that both body density and lean body weight can be predicted rather accurately from five simple anthropometric measures. The standard error of estimate was $\pm$ 2.4 kg.

In any particular age group of men or women the thickness of the layer of subcutaneous fat is related to the percent by weight of fat in the body (32). Approximately one half of the body's fat content is located in the tissues beneath the skin, therefore, the measurement of subcutaneous fat can yield an index of body fatness (33, 40).

Skinfolds have shown a good relationship to underwater weighing in the determination of total body fat (5, 11, 25, 32, 33, 60, 69). The skinfold method has the great merit of simplicity, speed and minor expense. The use of predictive equations from skinfolds to measure body fat is specific to the population from which the equations were divided. Equations must be different for males and females, and for different ages. The predictive equations when applied must be used on populations similar to the original samples (29, 39, 45, 63, 65, 75, 84). Also, greater skin compressibility is found in older adult males which makes the use of equations for college student unpredictive (14, 29, 68, 72).

Skinfold measures can be used in two ways. The first is to add the scores from the various measurements and use this value as an indication of the relative degree of fatness among subjects. The sum can be used to reflect changes in fatness before and after a physical conditioning program. A second way is in conjunction with the mathematical predictive equations discussed earlier.

The problems that might limit the accuracy of skinfold measures are: (1) improper use of equipment, (2) improper location of the site, (3) correct technique of lifting the fold, (4) improper placement of the instrument, and (5) selection of the appropriate equation (38).

ANTHROPOMETRIC EQUATIONS INVOLVING COLLEGE AGE MALES

The research literature contains a storehouse of equations available on a variety of population samples. With the use of regression equations and sophisticated statistical methods, such as stepwise multiple linear regression equations, formulas have been developed for the determination of body density from select skinfolds, circumferences, diameters or a combination of these measures. Jackson and Pollock (43) found that, through a four-year study of adult men, ages 18-61 men differed considerably in both age and body composition. Their model consisted of either the linear and quadratic or the logararithmic form and transformed the sum of skinfolds in combination with age and body circumference. From an earlier study by Jackson and Pollock (44) they found by factor analysis that skinfolds measured the same factor, therefore the skinfolds were summed. In the former study the sum of seven measurements provided a more stable estimate of subcutaneous fat. A second sum from chest, abdomen, and thigh measurements was also derived to provide a more feasible field estimate. The correlation between the sum of seven and the sum of three skinfolds was $r = 0.98$. Results of the regression analysis between the two equations were nearly identical. The sum of three skinfolds, because of the high correlation, would therfore be more feasible in a large group setting. These measurements were the first to have the ability to be used by all populations. An adaption of these measurements was made for the YMCA and the resulting skinfold equations were studied in this thesis.

Katch and Michael (50) found that in 17 year old high school boys the correlation between mean body density and illiac skinfold was r = .86. The illiac and chest skinfolds combined in a stepwise regression analysis were the best predictors. The prediction of body density and percent fat were improved greatly when girths (diameters) were added to the regression formula with skinfolds.

Pollock et al (65) did a multiple regression analysis on selected measures of young men ages 18-22 and 40-55 years old. He found that the slopes were equal for all analysis, but that the intercepts were different. These results provided further support for the need for different equations for these two populations. The most accurate prediction for young men was two skinfolds, four girths, and two diameters (r = .88). The standard error of prediction was equal to 0.0069 g/ml. The sites included the triceps and abdominal skinfolds, waist, ankle, calf, and chest girths and biacromial and bitrochanteric diameters. Pollock also developed an equation using skinfolds alone. He used three sites; the pectoral, subscapula, and thigh. The multiple correlation with the percent fat was r = .87. The standard error was .007 g/ml.

Haisman (41) conducted a study that looked at the assessment of body fat content in young men, mean age 22.6. It showed that the combined sites of either nine or of four sites have only a marginally higher correlation with body density (1770 to .772) than the single best site, the abdomen (.753). The nine sites included the subscapula, triceps, three sites on the chest, two sites on the abdomen, the suprailiac and the biceps. The four sites used were subscapula, triceps, suprailiac and biceps. The relationship of skinfold thicknesses at particular sites with body density showed that no one site was markedly superior to the others. Haisman found that the chest and abdomen skinfolds correlated better than the subscapula. The most important feature emerging from his study was that there was no advantage in adding information such as age, height and weight to skinfold thicknesses.

Sloan (72) estimated body fat in young males aged 18-26. Skinfolds were taken at seven sites: (1) thigh, (2) abdomen, (3) iliac, (4) chest, (5) scapula, (6) tricep, and (7) buttocks. The skinfold at the front of the thigh had the highest individual correlation with body density (r = .800). The best correlation of two skinfolds was the thigh and inferior angle of the scapula (r = .845).

Pascale (63) hoped the use of improved methods for the determination of body density and skinfold thicknesses would lead to more efficient prediction equations on young males. This did not occur. He found that the results were nearly identical to other studies. In his equation, Pascale used the skinfolds at the chest, tricep, and at the level of the xyphoid in the mid-axillary as the third.

Brozek and Keys (13) used a sample of 116 college men mean age 21.9. All were free of disease. One of the aims of the study was to develop equations for estimating the total fatness from more easily accessible measures of fatness than the specific gravity. The measures used included the abdomen, chest, subscapula, tricep and thigh measurements. The chest measurement had the highest correlation with specific gravity (0.857) with a standard error of .00757. The abdomen and tricep measurements were also very close in their correlations. These three measurements were put together to form a prediction equation for fatness-leanness that was studied in this thesis.

SUMMARY

A great many methods of measurement and estimation of body composition have been employed. The only direct measurement is cadaver analysis and this is seldom used because of its very nature. Of the other available laboratory techniques, the method used most often for the determination of body density (which correlates highly with percent of body fat) is that of underwater weighing. This method has been validated on numerous occasions and been deemed as quite reliable. Even though this method is reliable, it has a few drawbacks as do the other lab methods. These include expensive equipment and lengthy procedures.

Probably the most often used nonlaboratory technique has been the use of height-weight tables. This method is best used as a guide, but provides little in the way of body compostion makeup.

Research done in a nonlaboratory setting has prompted the formation and use of faster, more convenient equations to estimate percent of body fat. These equations involve the use of skinfolds, circumferences and diameters, either alone or in combinations. Numerous equations are available for individuals of all ages but this study has dealt with equations only for males 18-22 years old.

Chapter 3

PROCEDURES

This chapter describes the methods and procedures used in this study. Methods described include: selection of subjects, equipment, pre-test procedures, skinfolds, determination of density, estimation equations and statistical treatment.

SUBJECTS

Fifty young men from 18 to 22 years of age volunteered as subjects for this investigation. The group consisted of caucasian college students enrolled at Kansas State University. Thirty of the subjects were enrolled in required Concepts of Physical Education, twelve were enrolled in Lifetime classes and eight were enrolled in other classes on campus. The mean age and weight of the group was 20.1 years and 165.9 pounds. All subjects involved in the study signed an informed consent form which briefly outlined the purpose, procedures and risks involved before testing began (see appendix A).

EQUIPMENT

The equipment used in this study included:

1. A medical balance scale, manufactured by Douglas Homs Corporation, Belmont, California - calibrated to 1/16 lb.

2. Lange Skinfold Caliper - calibrated to .5 mm (Cambridge Scientific Industries, Inc., Cambridge, Maryland) and exerted a constant pressure on the caliper face of 10 gm/sq mm^2.

The underwater weighing system at Kansas State University is a modification of the system used by Akers and Buskirk (1).

3. Underwater weighing equipment included the following:

Tank, Water and Platform

a) The dimensions of the tank were 106 cm wide by 182 cm long by 188 cm deep. The walls were 15 cm thick and constructed of concrete.

b) The water used was tap (or city) water that fed directly into the tank. Both hot and cold water was used. The temperatures' range of the water was kept between 33-36^{o} C (95-97^{o} F). A sump pump to empty the water from the tank was also used.

c) The weighing platform consisted of an aluminum frame with a seat made of plastic chair webbing. The seat was 49 cm x 89 cm. The platform seat was 92 cm below the rim of the tank. The platform rested on four force cube transducers with bonded strain gauges.

Residual Volume Analyzer, Aluminum Kymograph, and Hosing

a) The residual volume analyzer was a 13.5 Liter Respirometer (Warren E. Collins, Inc., Boston, Massachusetts).

b) An aluminum kymograph drum and paper that measures the subjects respiratory patterns as well as the gas amounts added.

c) Added hosing was used with five pounds of lead weights attached to reduce the buoyancy of the hosing.

Temperature in the lab was kept between 85-89^{o} F for the comfort of the subject.

PRE-TEST PROCEDURES

Upon agreeing to become a subject each student signed an informed consent form explaining procedures and risks involved in the testing. (see Appendix A).

Prior to testing each subject was asked to refrain from eating any gas forming food for 24 hours. These foods include onions, beans or any spicy food that might be gas forming to the individual. He was asked to completely fast four hours prior to testing and to drink no liquids two hours prior to testing. Reasons for the pre-test instructions are that any gas in the intestines will cause subjects to appear more fat due to the bouyant force of the gas in the intestines. Also, food and liquid in the system would alter the land weight of the subject, making them heavier than usual.

After reporting to the lab each student was instructed to eliminate all body wastes. The students' land weight was then recorded to the nearest quarter pound. The subject was clothed only in nylon swim trunks which he wore for the remainder of the testing. Skinfolds were then recorded on each subjects data sheet. (see appendix B).

SKINFOLDS

Skinfold measurements were taken using the Lange Skinfold Caliper with a constant 10 gm/mm^2 pressure according to the procedures described by numerous investigators (12, 52, 63, 80). All skinfolds were taken on the right side of the body with the subject standing relaxed with his arms at his side. All measurements were taken to the nearest .5 mm.

The skinfolds were taken in the following manner as recommended by the committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council (52).

1. The skinfolds were grasped between the thumb and forefinger with the left hand. The skinfold included two thicknesses of skin and subcutaneous fat but not muscle.

2. A firm grip was used not exceeding the pain threshold.

3. The calipers were applied approximately ¼ to ½ inch from the thumb and forefinger at a depth equal to the thickness of the fold.

4. The skinfolds were repeated completely for each site before going on to the next site. A minimum of two measurements were taken and if those two differed by more than one mm a third measurement was necessary. The average of the three was then recorded.

The seven skinfolds and their anatomical landmarks were:

1. Subscapula - a fold taken along the inferior angle of the scapula, fold running parallel to the axillary border.

2. Tricep - a vertical fold on the posterior midline of the upper arm (over triceps), halfway between the acromion and olecranon process with the elbow extended and relaxed.

3. Pectoral - a diagonal fold one-half of the distance between the anterior-axillary line and the nipple.

4. Axilla - vertical fold on the mid-axillary line at approximately the level of the nipple.

5. Suprailiac - diagonal fold on the crest of the ilium at the mid-axillary line.

6. Abdominal - vertical fold adjacent to and approximately one inch to the right of the umbilicus.

7. Thigh - vertical fold on the anterior aspect of the thigh midway between the hip and knee joints.

DETERMINATION OF DENSITY

After the skinfolds had been recorded underwater weighing and residual volume measurements were taken at the same time using the

Closed Circuit Helium Dilution method described by Motley (60). The underwater weighing method used in this study was described by Buskirk (17).

In preparation for the testing the tank was filled at least 30 minutes prior to testing. Water temperature was kept within a range of 33-36 C. The water was allowed to settle as much as possible to give time here to free the tank of trapped air bubbles.

Prior to the beginning of the testing the subject received an explanation of the procedure. He was allowed to practice using the mouth-piece and simulated his movements while in the tank. Access to the tank was provided by an eight foot aluminum ladder. A minimum of one assistant was used throughout the testing procedures. After climbing into the tank the subject stood in the center of the tank and was fitted with an 11 pound weighted vest to prevent floating. The individual was manually assisted onto the weighing platform by the testers and sat in a comfortable position with his feet placed on the foot rest to ensure support and stabilization. The water level was checked to chin level to allow for complete submersion when bending over. The noseclip was fitted and the subject practiced submersion by slowly bending forward and lowering the trunk and head until the head was immersed in the water.

The residual volume analyzer and accompanying equipment were flushed with room air to remove any left-over gases. The helium meter was checked to make sure that the meter registerd zero and was ready to go. Three to five liters of room air was added to the system. The mouth piece valve was sealed to contain this air inside the spirometer. A reference line was recorded on the kymograph after which a known quantity of helium, usually about 1,000 cc BTPS, was added. The blower on the spirometer was turned on to completely mix the gases in the system. When equilibrium occured, the percentage of helium was recorded from the helium meter. This constituted the first helium reading.

The subject was fitted with the mouthpiece and weighted hoses. The blocks were removed from the strain gauges, and the testers were ready for the subject to submerge. When ready, the subject exhaled normally, held their breath and turned the valve on the mouthpiece so that they were connected into the spirometer circuit, and slowly bent forward until completely submerged. The subject was holding his breath in this position for approximately 6-8 seconds while his underwater weight was recorded. Upon a signal by one of the testers the subject sat slowly up and began breathing the mixture of gases in the analyzer.

The subject remained in the seated position while breathing the gaseous mixture for approximately three to four minutes or until equilibrium occurred. The expired air was filtered through a soda line mixture to remove carbon dioxide. Oxygen was added with the flow adjusted until the tidal volume training on the kymograph maintained a reasonably flat horizontal line. This rate of oxygen addition was equal to the rate of carbon dioxide removal and was to ensure a constant volume of gases in the system. The subjects breathing pattern was continuously recorded on the kymograph drum. Once the helium meter needle had stopped its descent and showed a constant reading the second helium percentage was recorded. Also recorded at this time was the temperature of air in the bell. This was later corrected to BTPS.

After making sure the blocks had been replaced in the strain gauges the subject was disconnected from the system and assisted off the weighing platform. The weighted vest was removed and placed back on the platform. The subject stood quietly, arms at their sides so as not to stir up the water, while the analyzer was flushed with air to remove the remaining helium. The mouthpiece was corked and placed near the vest to be weighed. This provided a reference line from which to calculate only the subject's weight not including the extra weight of the vest and mouthpiece. The entire procedure was repeated one or two more times to ensure accuracy of the underwater weight.

Calculation of the residual volume was based on the reduction of the relative concentration of helium when the subject's lungs were added to the system. The total volume of the analyzer was calculated from the known quantity of helium (1,000 cc) and its relative concentration (approx. 8%). When the subject's lungs were added to the system, the percentage of helium dropped due to the increase in the total system. This larger system volume minus the smaller system volume gives the volume of the system contributed by the lungs of the subject. This constituted the functional residual volume. The buoyancy force caused by the quantity of air was corrected for when the subject's density was calculated (17).

Difficulty in obtaining a reliable maximal expiration during underwater weighing made the use of measuring functional residual capacity (FRC) a more reliable procedure rather than residual volume. The calculation of FRC are as follows:

$$\text{Total Volume} = \frac{\text{Helium added in cc}}{\text{First Helium Meter Reading}}$$

$$\text{FRC Capacity} = \text{Total Volume} \times \frac{\text{Initial Helium Reading} - \text{Final Helium Reading}}{\text{Final Helium Reading}}$$

One hundred cc are subtracted from FRC to compensate for the subject's absorption of helium. The new FRC is then multiplied by the temperature correction factor (BTPS) of the gas in the system. This gives the corrected final Functional Residual Capacity.

Early in this study it was realized that the readings from the helium analyzer were too high. After carefully studying the nature of the problem and recalibrating the analyzer it was determined that the helium meter was giving a reading that was constantly high. Graphical procedures were implemented to correct for the error in subsequent tests. It appeared that the problem was corrected as it occurred, therefore, the validity of the results were not seriously compromised.

PREDICTION METHODS

Four estimation methods were used in this study; Each equation was population specific as specified by many investigators (3, 7, 12, 25, 28, 41).

1. Pollock et al (65) developed an equation using three skinfold sites; pectoral, subscapula, and thigh from 95 college students.

Density = 1.09716 - 0.00065 x Pectoral - 0.00055 x Subscapula - 0.0008 x Thigh

2. Brozek and Keys (13) used a sample of 133 males 18 to 26 years old and developed an equation using abdominal, pectoral, and tricep skinfold sites.

Density = Specific Gravity - .005

Specific Gravity = 1.1017 - 0.000282 x Abdominal - 0.000736 x Pectoral - 0.000883 x Tricep

Body density was changed to percent fat by use of two equations, Siri (70) and Brozek et al (12).

Siri % Fat = (4.950/D - 4.50) 100

Brozek % Fat = (4.570/D - 4.142) 100

3 and 4. Jackson and Pollock (44) developed skinfold tables for the YMCA which directly give percent fat based on the sums of the skinfolds and age. The original study sampled 403 males from 18 to 61 years old. The two tabels consist of conversions for the sum of six skinfolds and of four skinfolds for young males ages 18 to 22. The conversion tables are found in Appendix C. These equations were chosen from a personal communication with Dr. William Zuti (85). At this time publication of these equations are in press (85). The chart below gives the skinfold measures contained in each of the YMCA prediction methods:

YMCA #1	YMCA #2
1. Subscapula	1. Pectoral
2. Tricep	2. Axilla
3. Pectoral	3. Illiac
4. Illiac	4. Abdomen
5. Abdomen	
6. Thigh	

STATISTICAL TREATMENT

The use of correlation coefficients was used to determine how well the 24 variables correlated to each other. The mean, standard deviation, and the standard error of mean were computed for each variable. The difference between percent fat as estimated by each equation and percent fat as estimated by underwater weighing was calculated. These difference scores for each prediction method were compared using analysis of variance to determine which method was most accurate for this group of subjects. Consistency was compared using the standard deviation of the difference scores for each method.

Chapter 4

RESULTS AND DISCUSSION

This chapter includes the results of the data analysis, interpretation and discussion of the results, as well as the implications of these results.

DATA ANALYSIS AND INTERPRETATION PROCEDURES

The raw data of the 50 subjects for age, land weight, lean body weight, total body fat, density, and percent fat are listed in Appendix D. Appendix E is the percent of body fat values computed from the four skinfold estimation methods, and the difference between each of those methods compared to the value obtained from underwater for each subject. Hereafter, when percent body fat obtained by the underwater weighing method is referred to, the expression "% F water" will be used.

In review of each method the two YMCA equations used the sum of six and four sites. YMCA #1 used the sum of the tricep, chest, illiac, abdomen, thigh, and subscapula sites. YMCA #2 consisted of the sum of the chest, axilla, illiac and abdomen measurements. The method by Pollock used three sites; chest, subscapula, and thigh. The Brozek equation also used three sites but instead of the subscapula and thigh measures it used the tricep and abdomen. In putting the average of the four estimation methods together the equations overestimated the % F water on 27% of the 50 subjects. On eight of these there was less than a one percent overestimation. Of the 23 underestimated of the average of the four, three were less than one percent under.

The YMCA #1 method underestimated on 27 of the 50 subjects with one estimating precisely correct for % F water. In this regard YMCA #2 was identical to YMCA #1. The equation by Pollock underestimated on 27 of the

50 subjects with six identical to the % F water while Brozek's method was under on 33 of the subjects and over on 17 subjects.

RELIABILITY STUDY

In the use of skinfold estimation methods, accuracy of measurement is necessary to obtain the most accurate reading at each site and thus obtain as accurate an estimation of total body fat as possible.

Thirty-two subjects, not involved in the primary study, were used to check the reliability of the tester in measuring skinfolds. These subjects were drawn from the general student population of Kansas State University along with a few members of the graduate population in the department of HPER. Each subject had seven skinfolds taken twice with the second set of measurements taken 48 hours later. A minimum of two measurements were taken at each site. The results of the reliability study are listed in Table 1.

The correlation and standard error of measurement for the two trials are shown in Table 1. All seven sites showed a high correlation from trial I to trial II. The site that had the lowest standard error of measurement was the chest ($\pm$ .71 mm). The chest also had the second highest correlation of r = .986. The abdomen had the highest correlation of r = .988. The lowest correlation and highest standard error of measurement was the subscapula with r = .961 and SEM = 1.247 mm. This is still very encouraging because the correlation between the two trials is still very high and the two trial measurements only differed by a little over or under $\pm$ 1 mm on each subject. These results indicate that the reliability of the tester in taking skinfold measurements is acceptable.

Table 1

Reliability of Skinfolds

Skinfold Sites	Standard Deviation	Correlation	Standard Error Measurement
1. Subscapula	4.524	.961	± 1.27 mm
2. Tricep	4.055	.980	± .807 mm
3. Chest	4.226	.986	± .705 mm
4. Axilla	4.476	.979	± .913 mm
5. Illiac	5.419	.982	± 1.024 mm
6. Abdomen	5.492	.988	± .849 mm
7. Thigh	4.638	.979	± .946 mm

DESCRIPTIVE STATISTICS

This section contains descriptive statistics of variables related to the general characteristics of the population used in the study along with the individual skinfold measurements. This section also includes means and standard deviations of the body composition estimations from underwater weighing and the four estimation methods. The mean values, the standard deviations, and range for all varaibles are listed in Table 2.

Table 2

Mean, Standard Deviation, and Range of Body Composition Measures of 50 Males

Variable	Mean	Standard Deviation	Range
Age, Year	20.100	1.403	18.0 - 22.0
Wt., lb.	165.995	24.401	129 - 228
LBW, lb.	145.324	19,535	115.5 - 211.1
TBF	20.686	10.640	2.8 - 52.0
Density, g/ml	1.072	0.013	1.037 - 1.098
Subscapula, mm	12.79	3.52	7.0 - 23.5
Tricep, mm	12.18	3.44	6.0 - 20.5
Chest, mm	10.46	3.86	5.0 - 20.5
Axilla, mm	11.19	3.49	6.0 - 21.0
Illiac, mm	16.12	6.85	7.0 - 35.0
Abdomen, mm	15.78	6.10	7.0 - 33.0
Thigh, mm	14.25	3.832	9.0 - 32.0
% F Water	12.16	5.170	2.0 - 26.5
% F YMCA #1	11.96	4.063	5.8 - 23.5
% F YMCA #2	11.88	4.135	5.5 - 22.3
% F Pollock	11.80	2.899	8.4 - 22.5
% F Brozek	11.41	2.806	6.7 - 18.8

General Characteristics

One can see from Table 2 the wide range of subjects used. The variables used were age, land weight, lean body weight, total body fat, and density. The mean age of this population was 20.1 years old and the mean weight was 166 lbs. The range of body weight for the 50 subjects was from 129-228 lbs. Mean lean body weight (LBW) was 145 lbs. and the range from 115-211 lbs. The mean total fat was 20.7 lbs. per subject with scores ranging from 2.8-52 lbs. of body fat.

Skinfolds

In relation to the skinfold measurements the chest had the smallest mean thickness of 10.5 mm followed by the axilla, with a mean of 11.2 mm. The greatest mean thickness was the illiac skinfold with 16.1 mm followed closely by the abdomen with 15.8 mm. The smallest range of any one measurement belonged to the triceps with a range of 14.5 mm. This was followed closely by the axilla with 15.0 mm and the chest with a range of 15.5 mm between the lowest and highest readings. The highest range of measurements belonged to the illiac site with a difference of 28 mm followed closely by the abdomen with a difference of 26 mm. This follows that the illiac and abdomen sites had the highest mean thickness to go along with the largest range of measurements for the 50 subjects.

In relation to the variability for the seven sites the illiac and abdomen had the greater standard deviations. Their standard deviations were 6.85 mm and 6.10 mm respectively. The tricep skinfold measure had the smallest standard deviation with 3.44 mm.

Body Composition Measures

The % F as determined by hydrostatic weighing was used as the criterion variable in this study. Previous work in the area of body composition has shown that underwater weighing, with corrected residual volume, to be a valid technique for determining body density (7, 17, 39, 53, 81). The mean % F water of the 50 subjects in this study was 12.16%. Listed in Table 2 are the mean standard deviation and range of the percent fat obtained from underwater weighing and the four estimation methods.

Using the percent fat determined by underwater weighing as the standard, one can see that all four of the estimation methods had a lower mean percent of body fat compared to the percent fat obtained with the underwater weighing. The mean percentages obtained by the four estimation methods were 11.96 by YMCA #1, 11.88 by YMCA #2, 11.8 by Pollock, and 11.41 by Brozek's method. The lowest range of measurement and standard deviation belonged to the method by Brozek and Keys.

COMPARISON OF ESTIMATION METHODS

An intercorrelations matrix among all the determinations of percent body fat used in this study is listed in Table 3. This includes the criterion variable, underwater weighing, and the four skinfold estimation methods.

Table 3

Intercorrelation Matrix Among Four Estimations
of Percent Body Fat

	YMCA #1	YMCA #2	Pollock	Brozek	% F Water
% F Water	.788	.783	.748	.768	1.000
Brozek	.980	.949	.949	1.000	
Pollock	.966	.907	1.000		
	.975	1.000			
	1.000				

These results indicate a fairly high correlation between each of the percent fat values estimated by the skinfold estimation methods and % F water. The highest correlation between % F water and an estimation method was r = .79 by YMCA #1. This was followed closely be YMCA with r = .783. Among the four estimation methods the highest correlation occurred between YMCA #1 and the method by Brozek with r = .980. YMCA #1 correlated highly with all the methods with the lowest correlation being r = .966 by Pollock's method.

Table 4

Analysis of Variance Summary

	Sum of Squares	Mean Square	F Value
Model	2,085.2	40.1	38.17
Error	154.4	1.05	
Corrected Total	2,239.6		
	Anova SS	F-Value	PR > F
Subject	2,076.3		
Method	8.9	2.81	0.0408*

* Level .05 Confidence

Table 4 contains a summary of the analysis of variance comparing the means of the four estimation methods. As shown by PR >F value, a significant difference among the means for each method was found at the .05 level of significance. Table 5 shows the differences among the mean.

Specific group comparisons were done using the least significant difference method. A difference among the means of .402 was required for significance. The results indicated that the estimation method by Brozek was significantly different from both YMCA methods. There were no significant differences among the YMCA methods and the equation by Pollock.

Table 5

Mean and Standard Deviation of the Differences of the Values Obtained with the Estimation Methods

Estimation Method	Mean	Standard Deviation
YMCA #1	0.200	3.18
YMCA #2	0.284	3.21
Pollock	0.357	3.56
Brozek	0.749	3.51

In evaluating any estimation method, both accuracy and the precision must be examined. As shown in Table 5 the most accurate estimation method among the mean differences was YMCA #1 which utilized six sites. This was followed closely be YMCA #2. The least accurate method was the method by Brozek, which used three measurements. The precision was evaluated by comparing the standard deviations of the differences which clearly shows the most precise method to also be YMCA #1. The method by Pollock was found to be the least precise.

Table 6 presents a correlation matrix among all the determinations of percent body used in this study. This includes the independent variable, underwater weighing, which was used as our standard measurement.

This study also looked at each individual measured to see how each site correlated with underwater weighing. The correlations found by each site are listed in Table 6. No one site had a better correlation to underwater weighing than the top three estimation methods. The four sites with highest correlations; illiac, axilla, chest, and abdomen are the four sites that make up YMCA #2.

YMCA #1, which included six of the seven sites, had a higher correlation. The illiac site had the highest correlation with underwater weighing with an r = .771.

Table 6

Correlation Between Individual Measures
and % F Water

Variable	Correlation
Subscapula	.638
Tricep	.677
Chest	.744
Axilla	.764
Illiac	.771
Abdomen	.719
Thigh	.618

DISCUSSION

As shown in Table 7, YMCA #1 was the most accurate and precise method used in this study. The standard deviation of the means here is also the standard error of measurement, an index of measurement precision. The criterion used in this study was % fat estimation from underwater weighing. Knowing that % fat obtained by underwater weighing to be a more valid estimate of true percent fat we needed to obtain the precision of each skinfold method. The lowest standard error of measurement belonged to YMCA #1 with ± 3.2%. This was again followed by YMCA #2 with a SEM of ± 3.2% also. The highest SEM belonged to the method by Pollock + 3.67%. The method by Brozek had a SEM of ± 3.5%.

The multiple correlation coefficient of the present study was found to be slightly lower for the methods of Pollock and Brozek, than the original studies of the coefficients. The YMCA methods were adapted from previous studies and the data was not available. In his original study, Pollock had a correlation of R = .867 and Brozek found an R = .865. These lower correlations are to be expected because of sampling fluctuations. Using a prediction equation will, in most cases, yield a higher correlation on the population from which it was developed.

The mean value for percentage of fat in the present study was 12.2%. This value is very close to the mean values obtained by other investigators. Mean percent fat values reported by other include 13.4%, 13.6%, 10.1%, 14.6%, and 10.3% by Pollock (65), Durnin and Rahaman (27), Pascale (63), Brozek and Keys (13), Wilmore (78), and Sloan (72). The discrepancies are probably the result of the inherent differences between the samples represented in these studies.

The four top predictors of fat in this study were; weight, triceps, axillary, and thigh skinfolds. A possible new lineral regression equation that might be made for the use of the top four predictors to estimate fat might be: Percent fat = -75.69 + .56 (weight) + 1.54 (axilla) + 1.21 (thigh) + .97 (tricep). This equation was not run to see how it correlated with body fat scores, but as shown by the other methods an equation predicts fairly accurately on the population studied.

Looking at the best predictors in each estimation method we find some common and some different predictors than were found in this study. The common predictors among the top indicators found in this study and those found in the other methods excluding YMCA #1 (which uses six sites) are the thigh used in Pollock's, the tricep in Brozek's, and the axilla in YMCA #2. The major difference is the use of land weight found here as a top predictor.

The pectoral skinfold was used in all the estimation methods and the abdominal skinfold was used in three of the other methods.

The results indicate that all four estimation methods predict percent body fat fairly accurately with a small standard error of measurement. All four methods tended to underpredict the values obtained by underwater weighing for this population.

The results indicate that the more sites that are included within an estimation method the higher the precision with underwater weighing. Both of the methods by Brozek and Pollock used three skinfold sites and were the least accurate, whereas YMCA #2 used four sites and YMCA #1 contained six sites.

The estimation of percent body fat is very important to the athlete as well as the fitness enthusiast. A reliable method needs to be used. Finding percent body fat by underwater weighing is by far a more accurate and reliable method but the feasibility for mass testing is very poor. The use of skinfold estimation methods have been shown to estimate percent body fat fairly accurately. Skinfold can be taken very easily and a large number of individuals can be tested in a very short period of time. One needs to find the most accurate and precise skinfold method available. The results in this study indicate that the two new equations developed for the YMCA are more accurate and precise compared to the other methods evaluated.

The time available is a consideration as to whether one would use YMCA #1 or YMCA #2. This study indicates that the more sites one uses, the more accurate the method. Both methods correlate very highly to each other so one could substitute for the other depending upon the time you have available. YMCA #1 uses six sites and YMCA #2 uses four sites. If the time is available, though, the use of six sites is preferred because of the increased precision.

Another consideration that makes the two YMCA methods more appropriate is the ease of obtaining the estimated percent fat. The methods by Brozek and Keys, and Pollock use nomograms and tables to calculate density and percent body fat. The advantage of the two YMCA methods is that they can be summed and one can go directly to a table (Appendix C) to obtain the given percent fat. An advantage of using the two YMCA methods that does not apply specifically to this study but is very important in the area of body composition is that all equations are age specific whereas the YMCA methods can be used for all ages. The estimation methods used in this study were for 18-22 year old males. Tables for all ages are available in using the YMCA methods.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter contains a summary of the procedures and results found within this study. Also included are the conclusions drawn from this work as well as the recommendations for further study.

SUMMARY

Fifty males, 18 to 22 years of age, who were students at Kansas State University in the Spring of 1980 volunteered as subjects to compare the accuracy of four methods of estimating percent body fat in college age males. The four skinfold estimation methods were validated against percent fat obtained by hydrostatic weighing.

YMCA #1 used as its predictors for percent fat the sum of six sites; subscapula, tricep, chest, illiac, abdomen, and thigh. YMCA #2 used the sum of four sites; chest, axilla, illiac, and abdomen. The predictors in the equation by Brozek and Keys were the tricep, chest and abdomen measurements. Pollocks method used three predictors; the chest, subscapula, and thigh.

Each subject was clothed only in nylon swim trunks for the test. Every individual was given his own coded number along with having his land weight recorded to the nearest pound as well as the measurement of body fat at seven selected skinfold sites. After these procedures were accomplished the determination of body density and percent body fat was made using the underwater weighing tank and the helium dilution method for estimation of functional residual capacity.

Results showed a high correlation with underwater weighing for the four estimation methods with multiple correlations of: r = .79 and SEM = (± 3.2%)

for YMCA #1, r = .78 and SEM (± 3.2%) for YMCA #2, r = .77 and SEM = (± 3.5%) for Brozek and Keys and r = .75 and SEM (± 3.6%) for the method by Pollock.

A significant difference among the means was found at the .05 level of significance between the method by Brozek and the three other estimation methods. The most accurate and precise methods were the two methods derived for the YMCA.

CONCLUSION

Within the limits of this study it was shown that all four skinfold estimation methods are accurate predictors of percent body fat as determined by underwater weighing for college age males. The method by Brozek and Keys was found to be less accurate than the other three estimation methods.

RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that further research be conducted in this area with certain adaptations. The study should be repeated under the following conditions:

1. For a more precise reading of underwater weight the use of five to seven trials should be used instead of the mean of three trials.

2. Repeat the study working with a digital reading for helium analysis or use another dilution method.

3. Since YMCA #1 is the most accurate method for young males the study should be repeated to evaluate how well the YMCA #1 estimates percent fat for males over 22.

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APPENDIX A

Consent Form

CONSENT FORM

Kansas State University

Investigator: Todd Rohr
Department of HPER, (phone - 532-6240)
Advisor: Dr. Larry Noble

Title of Investigation: Validation of skinfold measurements to hydrostatic weighing

This is to certify that I ______________________________ volunteer to participate in a research investigation at Kansas State University under the supervision of the Department of Health, Physical Education and Recreation.

The procedures involved in this study and their risks are as follows: 1. Upon consent of participation in the study extra skinfolds will be taken to correspond to skinfold measures used in the equations. 2. Selection of a convenient time for underwater weighing. 3. At the time of the underwater weighing my weight in the air will be measured. 4. Procedures for underwater weighing and measurement of vital capacity will be explained. 5. Actual measurements for determination of vital capacity and underwater weight will be recorded. 6. Findings will be made available at the end of the investigation.

Risks and discomforts may include: 1. Inability to relax during actual underwater weighing. 2. Slight discomfort in the use of a mouth piece. 3. The main risk is the possibility of drowning, but the chance is probably no more than drowning in the bathtub. Research assistants will be used and they are trained in emergency procedures. I have read them and understand the nature of the study.

I understand that all results will be kept confidential with data processed using coded numbers. If the results of the study are prepared for publication, no participants will be identified by name.

I understand that in the event of physical injury resulting from the research procedure involved in this experiment, no financial compensation will be available since the regulations of the state prohibit Kansas State University from carrying insurance for such purposes.

I understand that questions I might have will be answered immediately on completion of the study and that results will be made available to me and that I can withdraw my consent at any time. I have the right to withdraw from participation in this project at any time.

I understand the procedures, potential risks, and agree to voluntarily take part in this study.

______________________	______________________
Date	Signature
______________________	______________________
Date	Witness

APPENDIX B

Data Sheet

Age________________

Code # ______________

Air Weight ______________

Phone ______________

Skinfolds

Scapular ________mm

Tricep ________mm

Pectoral ________mm

Axilla ________mm

Iliac ________mm

Abdomen ________mm

Thigh ________mm

% Fat = ______________

2. Brozek: Use Nomograms

Tricep ________mm

Pectoral ________mm

Abdomen ________mm

% Fat = ______________

3. Pollock: Young Males (18 - 22 yrs.)

	(mm)		(conversion)		
Pectoral	________	X	________	=	______________
Scapular	________	X	________	=	______________
Thigh	________	X	________	=	______________

Density = ______________

% Fat = ______________

4. Y.M.C.A.

Pectoral ________mm

Axilla ________mm

Iliac ________mm

Abdomen ________mm

% Fat = ______________

Water Weight ______________

Residual Volume ______________

Air Temperature ______________

Correction Factor ______________

% Fat ______________________________________

APPENDIX C

YMCA Estimation Methods for Male 18-22 Years Old

Table 7

Percent Fat Estimations from the Sum of Six Skinfolds
for 18-22 Year Old Males
(YMCA #1)

18-19 Years		18-19 Years		18-19 Years	
Sum	% Fat	Sum	% Fat	Sum	% Fat
37	3.7	62	8.5	87	12.9
38	3.9	63	8.7	88	13.0
39	4.1	64	8.8	89	13.2
40	4.3	65	9.0	90	13.3
41	4.5	66	9.2	91	13.5
42	4.7	67	9.3	92	13.7
43	4.9	68	9.5	93	13.8
44	5.1	69	9.7	94	14.0
45	5.3	70	9.9	95	14.1
46	5.5	71	10.0	96	14.3
47	5.7	72	10.2	97	14.5
48	5.9	73	10.4	98	14.7
49	6.1	74	10.6	99	14.8
50	6.2	75	10.8	100	15.0
51	6.4	76	11.0	101	15.2
52	6.6	77	11.2	102	15.3
53	6.8	78	11.3	103	15.5
54	7.0	79	11.5	104	15.6
55	7.2	80	11.7	105	15.8
56	7.4	81	11.8	106	16.0
57	7.6	82	12.0	107	16.1
58	7.7	83	12.2	108	16.2
59	7.9	84	12.3	109	16.4
60	8.1	85	12.5	110	16.5
61	8.3	86	12.7	111	16.7

Table 7 (continued)

18-19 Years		18-19 Years		18-19 Years	
Sum	% Fat	Sum	% Fat	Sum	% Fat
112	16.8	138	20.6	164	24.0
113	16.9	139	20.7	165	24.2
114	17.1	140	20.9	166	24.3
115	17.3	141	21.0	167	24.4
116	17.4	142	21.2	168	24.6
117	17.6	143	21.3	169	24.7
118	17.7	144	21.5	170	24.8
119	17.9	145	21.6	171	24.9
120	18.1	146	21.7	172	25.0
121	18.2	147	21.9	173	25.1
122	18.3	148	22.0	174	25.2
123	18.5	149	22.1	175	25.4
124	18.6	150	22.2	176	25.5
125	18.8	151	22.4	177	25.6
126	18.9	152	22.5	178	25.7
127	19.0	153	22.6	179	25.8
128	19.2	154	22.8	180	25.9
129	19.3	155	22.9	181	26.0
130	19.5	156	23.0	182	26.2
131	19.6	157	23.1	183	26.3
132	19.7	158	23.3	184	26.4
133	19.9	159	23.4	185	26.5
134	20.0	160	23.5		
135	20.2	161	23.7		
136	20.3	162	23.8		
137	20.5	163	23.9		

20-22 Years Sum	% Fat	20-22 Years Sum	% Fat	20-22 Years Sum	% Fat
37	4.1	63	9.1	89	13.6
38	4.3	64	9.2	90	13.7
39	4.5	65	9.4	91	13.9
40	4.7	66	9.6	92	14.1
41	4.9	67	9.7	93	14.2
42	5.1	68	9.9	94	14.4
43	5.3	69	10.1	95	14.5
44	5.5	70	10.3	96	14.7
45	5.7	71	10.4	97	14.9
46	5.8	72	10.6	98	15.1
47	6.0	73	10.8	99	15.2
48	6.1	74	11.0	100	15.4
49	6.3	75	11.2	101	15.6
50	6.5	76	11.4	102	15.7
51	6.6	77	11.6	103	15.9
52	6.8	78	11.8	104	16.0
53	7.0	79	11.9	105	16.2
54	7.2	80	12.1	106	16.4
55	7.4	81	12.2	107	16.5
56	7.6	82	12.4	108	16.6
57	7.8	83	12.6	109	16.8
58	8.1	84	12.8	110	16.9
59	8.3	85	12.9	111	17.0
60	8.5	86	13.1	112	17.2
61	8.7	87	13.3	113	17.3
62	8.9	88	13.4	114	17.5

Table 7 (continued)

20-22 Years		20-22 Years		20-22 Years	
Sum	% Fat	Sum	% Fat	Sum	% Fat
115	17.7	137	20.9	159	23.8
116	17.8	138	21.0	160	23.9
117	18.0	139	21.2	161	24.0
118	18.1	140	21.3	162	24.1
119	18.3	141	21.4	163	24.2
120	18.5	142	21.6	164	24.4
121	18.6	143	21.7	165	24.5
122	18.7	144	21.9	166	24.6
123	18.9	145	22.0	167	24.7
124	19.0	146	22.1	168	24.8
125	19.2	147	22.3	169	25.0
126	19.3	148	22.4	170	25.1
127	19.4	149	22.5	171	25.2
128	19.6	150	22.6	172	25.3
129	19.7	151	22.8	173	25.4
130	19.9	152	22.9	174	25.6
131	20.0	153	23.0	175	25.7
132	20.2	154	23.2	176	25.8
133	20.3	155	23.3	177	25.9
134	20.4	156	23.4	178	26.0
135	20.6	157	23.5	179	26.2
136	20.7	158	23.6	180	26.3

Table 8

Percent Fat Estimation from the Sum of Four Skinfolds
for 18-22 Year Old Males
(YMCA #2)

18-19 Years		18-19 Years	
Sum	% Fat	Sum	% Fat
22	4.3	46	10.2
23	4.6	47	10.4
24	4.8	48	10.6
25	5.1	49	10.8
26	5.3	50	11.1
27	5.6	51	11.3
28	5.8	52	11.5
29	6.1	53	11.7
30	6.3	54	11.9
31	6.6	55	12.2
32	6.8	56	12.4
33	7.0	57	12.6
34	7.3	58	12.8
35	7.5	59	13.0
36	7.8	60	13.3
37	8.0	61	13.5
38	8.2	62	13.7
39	8.5	63	13.9
40	8.7	64	14.1
41	9.0	65	14.4
42	9.2	66	14.6
43	9.4	67	14.8
44	9.7	68	15.0
45	9.9	69	15.2

Table 8 (continued)

18-19 Years Sum	% Fat	18-19 Years Sum	% Fat
70	15.4	99	20.9
71	15.6	100	21.1
72	15.8	101	21.2
73	16.0	102	21.4
74	16.2	103	21.6
75	16.4	104	21.8
76	16.6	105	22.0
77	16.8	106	22.1
78	17.0	107	22.3
79	17.2	108	22.5
80	17.4	109	22.6
81	17.6	110	22.8
82	17.8	111	23.0
83	18.0	112	23.1
84	18.2	113	23.3
85	18.3	114	23.4
86	18.5	115	23.6
87	18.7	116	23.7
88	18.9	117	24.0
89	19.1	118	24.1
90	19.3	119	24.2
91	19.5	120	24.4
92	19.7	121	24.5
93	20.0	122	24.7
94	20.1	123	24.9
95	20.2	124	25.0
96	20.4	125	25.2
97	20.6		
98	20.8		

Table 8 (continued)

20-22 Years Sum	% Fat	20-22 Years Sum	% Fat
22	4.7	49	11.2
23	4.9	50	11.5
24	5.2	51	11.7
25	5.4	52	11.9
26	5.7	53	12.1
27	5.9	54	12.3
28	6.2	55	12.6
29	6.4	56	12.8
30	6.7	57	13.0
31	6.9	58	13.2
32	7.2	59	13.4
33	7.4	60	13.7
34	7.7	61	13.9
35	7.9	62	14.1
36	8.2	63	14.3
37	8.4	64	14.5
38	8.6	65	14.7
39	8.9	66	14.9
40	9.1	67	15.1
41	9.4	68	15.3
42	9.6	69	15.5
43	9.8	70	15.8
44	10.1	71	16.0
45	10.3	72	16.2
46	10.6	73	16.4
47	10.8	74	16.6
48	11.0	75	16.8

Table 8 (continued)

20-22 Years Sum	% Fat	20-22 Years Sum	% Fat
76	17.0	102	21.8
77	17.2	103	22.0
78	17.4	104	22.2
79	17.6	105	22.3
80	17.8	106	22.5
81	18.0	107	22.7
82	18.2	108	22.9
83	18.4	109	23.0
84	18.6	110	23.2
85	18.7	111	23.3
86	18.9	112	23.5
87	19.1	113	23.7
88	19.3	114	23.8
89	19.5	115	24.0
90	19.6	116	24.1
91	19.8	117	24.3
92	20.0	118	24.4
93	20.2	119	24.6
94	20.4	120	24.7
95	20.5	121	24.9
96	20.7	122	25.0
97	20.9	123	25.1
98	21.1	124	25.3
99	21.3	125	25.5
100	21.4		
101	21.6		

APPENDIX D

Raw Data

Table 9

RAW DATA

Subject	Age	Weight	LBW	TBF	Density	% Fat
01	19	152.00	137.2	14.8	1.0779	9.8
02	22	228.00	211.1	16.9	1.0840	7.4
03	21	152.75	132.2	20.6	1.0686	13.5
04	20	161.00	143.3	17.7	1.0749	11.0
05	21	133.50	120.9	12.6	1.0788	9.4
06	20	129.00	115.5	13.5	1.0762	10.4
07	21	140.00	125.9	14.1	1.0772	10.1
08	22	163.00	150.1	12.9	1.0826	7.9
09	21	171.75	141.4	30.4	1.0583	17.7
10	21	204.00	175.4	28.6	1.0673	14.0
11	21	160.50	150.4	10.1	1.0868	6.3
12	19	190.75	148.o	42.7	1.0467	22.4
13	20	163.00	155.4	7.6	1.0910	4.7
14	21	133.25	126.00	7.3	1.0891	5.4
15	18	167.75	160.4	7.4	1.0917	4.5
16	18	148.75	142.4	6.4	1.0920	4.3
17	19	167.25	153.1	14.1	1.0813	8.4
18	19	221.75	183.8	27.9	1.0596	17.1
19	18	211.25	190.9	20.4	1.0782	9.6
20	19	149.25	129.0	20.8	1.0675	13.9
21	18	164.50	120.0	34.5	1.0500	21.0
22	19	160.25	142.8	17.5	1.0751	10.9
23	22	157.50	147.9	9.6	1.0874	6.1

Table 9 (continued)

Subject	Age	Weight	LBW	TBF	Density	% Fat
24	19	177.25	156.0	21.3	1.0723	12.0
25	22	171.75	142.3	29.5	1.0594	17.2
26	22	150.75	130.7	20.1	1.0678	13.8
27	21	143.25	127.1	16.2	1.0741	11.3
28	19	153.00	133.6	19.4	1.0705	12.7
29	18	186.75	168.3	18.5	1.0776	9.9
30	22	204.75	163.8	41.0	1.0515	20.0
31	20	168.25	137.7	30.6	1.0570	18.2
32	21	168.50	142.5	26.0	1.0638	15.4
33	22	151.50	134.0	17.5	1.0734	11.6
34	21	219.25	176.8	42.4	1.0541	19.3
35	19	153.25	139.8	13.4	1.0805	8.8
36	19	184.25	148.3	35.9	1.0537	19.5
37	20	152.75	136.4	16.4	1.0755	10.7
38	22	198.00	176.2	21.8	1.0748	11.0
39	22	196.50	144.5	52.0	1.0371	26.5
40	19	182.50	150.5	32.0	1.0586	17.5
41	18	141.50	123.4	18.1	1.0704	12.8
42	22	145.75	133.8	12.0	1.0707	8.2
43	19	151.00	133.3	17.7	1.0728	11.7
44	19	147.00	131.4	15.6	1.0758	10.6
45	19	148.00	127.3	20.7	1.0673	14.0
46	21	146.00	120.0	25.0	1.0597	17.1
47	20	183.75	164.00	19.8	1.0753	10.8
48	18	154.75	134.1	20.7	1.0689	13.4
49	20	152.00	142.5	9.5	1.0869	6.3
50	22	136.50	133.7	2.8	1.0979	2.0

APPENDIX E

Estimations of Percent Fat from Skinfold Estimation Equations and Differences from % F Water Values

THE FOLLOWING PAGE HAS A CUT OFF PAGE NUMBER.

THIS IS AS RECEIVED FROM CUSTOMER.

Table 10

Estimation of Percent Fat from Skinfold Estimation Equations
and Differences from % F Water Values

Subject	% F Water	Y_1 %	Diff	Y_2 %	Diff	Poll %	Diff	Broz %	Diff	Range
01	9.8	12.2	+2.4	11.1	+1.3	12.4	+2.6	11.8	+2	+1.3 - +2.6
02	7.4	14.2	+6.8	15.2	+7.8	12.7	+5.3	12.5	+5.1	+5.1 - +7.8
03	13.5	9.9	-3.6	10.8	-2.7	9.2	-4.3	10.0	-3.5	-2.7 - -4.3
04	11.0	9.7	-1.3	10.0	-1.0	9.8	-1.2	10.1	- .9	- .9 - -1.2
05	9.4	8.7	- .7	8.4	-1.0	9.5	+ .1	8.6	- .8	-1.0 - .8
06	10.4	12.4	+2.0	12.3	+1.9	12.2	+1.8	11.1	+ .7	+ .7 - +2.0
07	10.1	12.4	+2.3	13.0	+2.9	12.2	+2.1	10.7	+ .6	+ .6 - +2.9
08	7.9	9.3	+1.4	9.0	+1.1	9.9	+2.0	9.2	+1.3	+1.1 - +2.0
09	17.7	12.6	-5.1	13.0	-4.7	11.8	-5.9	12.4	-4.3	-4.3 - -5.9
10	14.0	12.0	-2.0	11.0	3.0	12.2	-1.8	11.5	-2.5	-2.5 - 3.0
11	6.3	9.3	3.0	8.0	1.7	10.6	4.3	9.6	3.3	1.7 - 4.3
12	22.4	23.5	1.1	22.3	- .1	22.5	.1	18.8	-3.6	-3.6 - 1.1
13	4.7	7.8	3.1	7.7	3.0	8.7	4.0	8.8	4.1	3.0 - 4.1
14	5.4	9.5	4.1	9.7	4.3	9.2	3.8	9.0	3.6	3.6 - 4.3
15	4.4	11.2	6.8	9.9	5.5	11.3	6.9	11.4	7.0	5.5 - 7.0
16	4.3	6.3	2.0	6.0	1.7	8.5	4.2	8.0	3.7	1.7 - 4.2
17	8.4	7.3	-1.1	7.4	-1.0	8.4	0	8.2	- .2	-1.1 - 0

Table 10 (continued)

Subject	% F Water	Y_1 %	Diff	Y_2%	Diff	Poll %	Diff	Broz %	Diff	Range
18	17.1	16.0	-1.1	7.4	-1.0	8.4	0	8.2	- .2	-1.1 - .0
19	9.6	10.8	1.2	11.7	2.1	10.0	.4	11.0	1.4	.4 - 1.4
20	13.9	10.8	-3.1	9.3	-4.6	12.0	-1.9	11.4	-2.5	-4.6 - -1.9
21	21.0	12.8	-8.2	11.9	-9.1	12.8	-8.2	11.3	-9.7	-9.7 - -8.2
22	10.9	13.3	2.4	13.9	3.0	13.2	2.3	13.5	2.6	2.3 - 3.0
23	6.1	9.7	3.6	9.6	3.5	10.0	3.9	10.0	3.9	3.5 - 3.9
24	12.0	8.5	-3.5	10.3	-1.7	9.1	-2.9	9.3	-2.7	-3.5 - -1.7
25	17.2	18.7	1.5	19.6	2.4	15.8	-1.4	16.1	-1.1	-1.4 - 2.4
26	13.8	15.8	2.0	12.8	-1.0	15.9	2.1	14.9	1.1	-1.0 - 2.1
27	11.3	12.8	1.5	11.4	.1	12.4	1.1	12.0	.7	.1 - 1.5
28	12.7	13.5	.8	13.8	1.1	12.8	.1	12.4	- .3	- .3 - 1.1
29	9.9	9.0	- .9	8.5	-1.4	10.0	.1	8.6	-1.3	-1.4 - .1
30	20.0	22.6	2.6	22.3	2.3	19.9	- .1	18.1	-1.9	-1.9 - 2.6
31	18.2	16.9	-1.3	17.0	-1.2	13.7	-4.5	15.2	-3.0	-4.5 - -1.2
32	15.4	13.6	-1.8	12.8	-2.6	12.6	-2.8	11.4	-4.0	-4.0 - -1.8
33	11.6	10.6	-1.0	9.6	-2.0	11.6	0	10.7	- .9	-2.0 - 0
34	19.3	20.2	.9	21.6	2.3	15.9	-3.4	17.4	-1.9	-3.4 - 2.3
35	8.8	8.8	0	8.4	- .4	9.4	.6	9.8	1.0	- .4 - 1.0

Table 10 (continued)

Subject	% F Water	Y_1 %	Diff	Y_2 %	Diff	Poll %	Diff	Broz %	Diff	Range
36	19.5	19.0	- .5	18.6	- .9	16.7	-2.8	16.7	-2.8	-2.8 - - .5
37	10.7	9.1	-1.6	9.8	- .9	9.8	- .9	8.9	-1.8	-1.8 - - .9
38	11.0	10.4	- .6	11.7	.7	10.2	- .8	9.8	-1.2	-1.2 - .7
39	26.5	17.3	-9.2	18.0	-8.5	15.0	-11.5	14.0	-12.5	-12.5 - -8.5
40	17.5	15.4	-2.1	15.2	-2.3	13.5	-4.0	14.2	-3.2	-4.0 - -2.1
41	12.8	8.7	-4.1	8.0	-4.8	10.1	-2.7	9.0	-3.8	-4.8 - -2.7
42	8.2	7.9	- .3	9.2	1.0	9.4	1.2	8.6	.4	- .3 - 1.2
43	11.7	7.9	-3.8	6.8	-3.9	9.6	-2.1	8.9	-2.8	-3.9 - 2.1
44	10.6	8.4	-2.2	9.0	-1.6	9.7	- .9	9.6	-1.0	-2.2 - - .9
45	14.0	10.9	-3.1	11.1	-2.9	11.5	-2.5	11.7	-2.3	-3.1 - -2.3
46	17.1	14.7	-2.4	14.4	-2.7	13.1	-4.0	14.0	-3.1	-4.0 - -2.4
47	10.8	8.7	-2.1	8.9	-1.9	9.2	-1.6	9.3	-1.5	-2.1 - -1.5
48	13.4	12.7	- .7	14.0	.6	12.1	-1.3	11.8	-1.6	-1.6 - .6
49	6.3	8.4	2.1	7.9	1.6	9.7	3.4	8.8	2.5	1.6 - 3.4
50	2.0	5.8	+3.8	5.5	3.5	8.6	6.6	6.7	4.7	3.5 - 6.6

THE RELATIVE ACCURACY OF FOUR SKINFOLD ESTIMATION METHODS IN PREDICTING THE PERCENT BODY FAT OF COLLEGE MALES

by

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ABSTRACT

Fifty males 18 to 22 years old enrolled at Kansas State University, volunteered as subjects to compare the accuracy of four skinfold estimation methods for use in the estimation of percent body fat of college age males. Four estimation methods were validated against the percent fat obtained by hydrostatic weighing. The multiple correlations and the standard error of measurement when compared to underwater weighing were: r = .79 (± 3.2%), r = .78 (± 3.2%), r = .77 (± 3.5%), and r = .75 (± 3.6%) for the methods by YMCA #1, YMCA #2, Brozek and Keys, and Pollock et al, respectively.

YMCA #1 used the sum of six sites; subscapula, tricep, chest, illiac, abdomen, and thigh. YMCA #2 also summed its measurements but used only four sites; chest, axillam illiac, and abdomen. The method by Brozek and Keys used three sites; the tricep, chest, and abdomen. Pollock et al also used three predictors; the chest, subscapula, and thigh. Using an analysis of variance and the least significant difference method, a significant difference was found at the .05 level of significance between the method by Brozek and Keys and the other three estimation equations. Findings indicate that all four estimation methods are accurate estimators of percent body fat for college age males.