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UNDERWATER WEIGHING VALIDATION OF THREE SKINFOLD ESTIMATION TECHNIQUES FOR USE ON COLLEGE FEMALES

by

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B. S., East Stroudsburg State College, 1978

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Health, Physical Education and Recreation

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Approved by:

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Major Professor

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ACKNOWLEDGEMENTS

Sincere appreciation is expressed to those who served on my committee, Dr. David Laurie and Dr. Kathleen Newell, for their help and guidance. Special appreciation is extended to Dr. David Laurie for providing invaluable moral support when it was most needed. Appreciation is expressed to Dr. Mary McElroy and Dr. Authur Dayton for their assistance with the statistical analysis of the data, and thanks also goes to Dr. Larry Noble and Dr. Pat McSweigen for their assistance in the interpretation of the data.

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Chapter 1

INTRODUCTION

The incidence of obesity in America has been on the rise for the past century (46). Many social and cultural factors have contributed to the cause of obesity. The abundance of rich foods and drinks, increases in automation and technology, and the sedentary life styles prevalent today are the major contributors to the occurrence of obesity (3,34).

Obesity is detrimental to an individual's health. Research has indicated that excessive fat contributes to the occurrence of such problems as cardiovascular diseases, hypertension, degenerative diseases of the heart and vessels, diabetes, gall bladder disorders, cirrhosis of the liver, and certain forms of cancer (3,32,58,59). The life span of the obese individual may be shorter than that of a person of "normal" body weight. According to life insurance data, the mortality rate for women moderately overweight is 42% more than the standard risk, and for markedly overweight women, the data reports a mortality rate of 61% above the standard risk (59).

Obesity is the result of ingesting more energy than is expended. The excess energy is stored in the form of fat droplets in adipose tissue. The commonly accepted criterion of obesity is being 20% or more above ideal chart weight or, for women, having 30% or more of the body weight as fat.

Obesity can occur at any time in life. In many instances it occurs with a change in a person's mode of life. For instance, upon graduation from college or high school, a person's activity level often is abruptly diminished while their eating patterns remain as they previously were when the individual was more active, resulting in a weight gain. In women, excessive weight gain is likely to occur after completion of physical growth at approximately 19-21 years of age (34). This period of time corresponds to the previously mentioned time, thereby compounding the potential for obesity.

In the past, height-weight tables were the most extensively used tool in determining overweight. Keys and Brozek (56) showed that these standards are quite limited in their ability to accurately identify degrees of obesity. Individuals of muscular body types have been classified as overweight and even obese in terms of the height-weight tables, yet in actuality, they have very little body fat on their frames. This indicates that the terms "overweight" and "overfat" do not refer to the same condition, and that height-weight tables cannot be used to determine overfatness. The composition of the body must be known in order to assess fatness.

There are several methods available that can be employed in determining body composition. The technique used depends upon the requirements of the investigator and on the purpose of the study. Laboratory methods such as hydrostatic weighing, soft tissue x-ray, potassium-40, creatinine excretion, chemical analysis, and total body water inherently limit their own use. For the large part, they require expensive, cumbersome, and complex equipment, involve technical procedures, and require a great deal of time. The difficulties presented by these methods created the need for simple, rapid procedures which would estimate percent body fat with reasonable precision, yet involve a minimal amount of time, effort, and expense.

Anthropometry is the most widely used field method for determining body composition. Included in this area are measures of skinfolds, circumferences, and diameters. Equations have been developed which include one or more of those measures. Their results were validated against values of density and percent body fat obtained by underwater weighing. Today there are numerous equations available which involve skinfolds, circumferences, diameters, or a combination of these measures for estimation of body density. The equations are specific to the population for which they were formulated. The equations are limited by sex and age, and in some cases, levels of fitness. In each subdivision according to age and sex, there remains a number of equations available for use. The problem is determining which equation(s) is most accurate in estimating body density for the population to which the equation will be applied.

Three equations for estimating body density from skinfold measures alone were examined in this study. The equations involve a combination of different skinfold sites. All equations involved in this study were formulated for college age women. The first equation was developed by Sloan et al. (90) and uses the tricep and iliac crest skinfolds. The second equation considered in this study was the result of research conducted by Pollock et al. (79) and involves the iliac crest and thigh sites. Lastly, this study examined Pollock's YMCA equation which uses the tricep, iliac crest, and abdomen sites.

STATEMENT OF THE PROBLEM

The purpose of this study was to determine which of three skinfold equations was the most accurate predictor of percent body fat in young women. More specifically, the purpose of this study was to determine the validity of three skinfold equations used for prediction of density and percent body fat in young women, between the ages of 18 and 22 years, by comparing their resultant values to values obtained by underwater weighing.

LIMITATIONS

The validity of this study may have been affected by the following limitations:

1. Subjects were female volunteers who were aware of the testing procedures.

2. Only three of a multitude of skinfold equations for a population of young women, ages 18-22 years, were examined.

DELIMINATIONS

The scope of this study and the confines for generalizations from the study were restricted by the following:

1. The study was delimited to 47 volunteer female students, 18-22 years of age, enrolled at Kansas State University during the Spring semester, 1980.

2. Skinfold equations were validated against the density value obtained by underwater weighing procedures. This value was assumed to be a valid measure of body composition.

DEFINITION OF THE TERMS

The following terms are defined to facilitate a better understanding of the study by the reader:

Body Density

Body density is the body's air weight or mass, divided by the body volume.

Body Volume

Body volume is the volume of the body as determined by the loss of weight in water or by the volume of water displaced upon submersion.

Functional Residual Capacity

Functional residual capacity is the volume of air remaining in the lungs and airways following a normal exhalation. It is the residual volume plus the expiratory reserve.

Land Weight

Air or land weight is the weight of the subject to the nearest ounce, as determined by a Medical Balance Scale, while clad in a one piece nylon swim suit.

Lean Body Weight

Lean body weight (LBW) is the total weight of the body with all fat removed.

Percent Body Fat

Percent body fat is the total body fat divided by the air or land weight, and expressed as a percentage of the total body weight.

Residual Volume

Residual volume is the amount of air remaining in the lungs and airways after a maximal exhalation.

Total Body Fat

Total body fat (TBF) is the lean body weight subtracted from the land weight.

Underwater Weight

Underwater weight is the weight of the body when it is totally submerged in water. This value is corrected for the buoyant effect elicited by the residual volume of air in the lungs at the time of underwater weighing.

Chapter 2

REVIEW OF THE LITERATURE

This chapter presents a review of pertinent literature related to laboratory methods of assessing body composition, field techniques for estimation of body composition, underwater weighing as a means of determining body density, and the measurement of residual lung volume.

LABORATORY METHODS FOR ASSESSING BODY COMPOSITION

The human body is basically divided into two major measuring compartments, with fat constituting one and bone and muscle mass the other. When determining the composition of the body, the fat component is expressed as a percentage of the body's total weight. If bone and muscle mass are being assessed, they are expressed in terms of lean body mass. Once one of the two components is known, the unknown component can be calculated from the known value. This section of the literature review will discuss several laboratory techniques which assess these two bodily constituents.

Cadaver Analysis

There is only one means of directly measuring the composition of the body, and that is by dissection and analysis of human cadavers. Body fat and lean body mass have been analyzed physically and chemically quite accurately using this technique (15,61,68,86). Due to the difficulty in obtaining cadavers, research is limited in this area, therefore the analysis of animal carcases has been more convenient than that of human cadavers. Results obtained through animal analysis have been extended to the human population (15,18,78).

Biochemical Techniques

A second means of assessing body composition is by biochemical techniques. Measurements of K-40 and electrolytes, creatinine excretion, and total body water are methods in this category.

Total body water. The amount of water contained in the body is assumed to relatively constant and found mainly in lean body mass (87). Fat tissue contains very little water (12,56,70). If the water content of the body is known, the amount of body fat can be determined. Several dilution methods are available for measuring the amount of water in the body. A tracer element such as deuterium oxide, tritium oxide, or antipyrine is introduced into the body. These elements are exchangable to all water compartments of the body. After sufficient time has elapsed for complete dilution of body water with the element, the bodily excretions are analyzed to measure amounts of the tracer element present. The difference between the concentrations is used to determine the lean body mass (29). Rathburn and Pace (81) demonstrated in experimentation with guinea pigs that there was a high inverse relationship between ether-extractable fat and total body water, therefore, knowledge of the body's water content can be used in determining lean body mass and the further estimation of percent body fat.

Electrolytes and K-40. Electrolyte concentrations have been used in the estimation of body composition. The measurable electrolytes are sodium (Na+), potassium (K+), and chlorine (Cl+). These elements occur naturally in the body's lean tissues. The principle underlying this method is similar to that which determines total body water. A known amount of one of these electrolytes is consumed and after an equilibration period which allows for complete exchange of the element into lean tissue, the concentration of the element is analyzed in the urine. The difference between the amount ingested and the amount excreted indicates the amount of lean tissue in the body (10,69).

The K-40 technique involves the ingestion of radioactive potassium. After allowing 24-48 hours for equilibration, the individual is placed under a whole body counter which records the amount of radioactive K that was absorbed into the body's leans tissues. The amount of potassium retained by the lean tissue indicates the size of the lean body mass (20,67,70,87).

Creatinine excretion. Creatinine is a byproduct of the metabolism of lean tissue (70). This technique is based on the assumption that the amount of creatinine excreted in the urine is a valid indicator of the body's muscle mass. A flaw in this reasoning occurs in that tissues other than skeletal muscle contribute to the amount of creatinine excreted, thereby rendering this method of determining body composition as questionable (41).

Soft Tissue X-ray

X-rays of body segments have been taken and analyzed to determine the thickness of the fat pads in particular areas of the body. The x-rays depict the fat-plus-skin shadows as well as the underlying bone. Through their use, fat can be measured at an individual site or an estimation of total body fat can be determined. The majority of research involving the use of soft tissue x-rays has been conducted by

Garn (36,37,39,40,42).

Ultrasound

The principle of ultrasound is quite similar to that of the radiographic methods. Ultrasound produces a graphic picture of the bone, muscle, and fat in a particular area of the body. The bone, muscle and fat can be distinguished from one another in the recording due to the fact that sound waves are slowed as they penetrate the more dense tissues (10).

UNDERWATER WEIGHING

By far the most widely used laboratory method for determining body composition is by densiometry (6,7,16,43,81). This technique determines the density of the body. The principle of body density assumes all humans are identical in the composition of their bodies except for individual differences in their proportions of adipose tissue. The lean body mass and fat have constant, but different densities. There is an inverse relationship between body density and fat content (85,89). The density of fat is variable, depending on age, sex, and rate of weight gain/loss (8,37). It is therefore advisable to use the density of ether-extracted fat, that being 0.90. The density of fat is less than the density of lean body mass, and hence, the larger the proportion of the body that is fat, the lower will be the body's density (17,23,56). When an object's density is known, percent fat and lean body mass can be calculated.

The underwater technique involves the application of Archimedes principle of water displacement:

$$\text{density} = \text{mass}/\text{volume}$$

This principle states that a body immersed in a fluid is acted upon by a buoyant force. The force is evidenced by a loss of weight in the object equal to the weight of the displaced fluid.

In 1915, Spivak (92) used this density principle in the underwater weighing of humans with "successful" results, although no corrections for residual volume were made.

By improvising the underwater weighing method employing Archimedes principle for determination of body density, and by compensating for the air remaining in the lungs at the time of weighing, Behnke et al. (8) were able to demonstrate a high correlation between "overweight" and density. They found underwater weighing to be a good indicator of an individual's relative "leanness or fatness".

Rathburn and Pace (81) formulated a quantitative relationship between body density and depot fat in guinea pigs by comparing underwater weighing results with values obtained by chemical analysis of the animal. They found that as body density increased, the fat content decreased. Their equation for estimation of percent fat from body density is:

$$\text{Fat\%} = (5.548/\text{density} - 5.044)\ 100$$

Keys and Brozek (56) formulated their own equation for estimation of percent fat from a known body density. The equation was not used often by other investigators due to the fact that an average residual volume was determined and used on all subjects rather than measuring residual volume individually. The equation is as follows:

$$\text{Fat\%} = (4.570/\text{density} - 4.142)\ 100$$

$$\left(\frac{4.95}{Bd} - 4.5\right) 100$$

The works of many men have demonstrated that the use of underwater weighing to estimate body density is a valid and reliable determination of the composition of the body. Brozek et al. (8) stated that the low density of fat makes the measurement of body density a valid means of estimating the fat content of the body. They also claimed that of all the available methods for estimating proportions of fat in the living body, the determination of body density by underwater weighing is the most reliable.

Keys and Brozek (56) measured the density of 35 trained subjects on two separate occasions, with one week's time between measures. The reliability coefficient was +.95, thus validating the ability of the underwater technique to accurately reproduce the density measures. The investigators stated that the estimation of body fat from density values was subject to a considerable degree of error, but added that it was the most reliable method available.

The major source of error in determining body density stems from inaccurate estimates of the air remaining in the lungs at the time of the underwater weighing. This volume is termed residual volume. A second air volume that could possibly affect the determination of an accurate body density is the amount of air in the gastrointestinal (GI) tract. According to Goldman and Buskirk (44), corrections for gas in the GI tract can be ignored since this volume is relatively small, less than 100 ml., if the pretest procedures were followed. The present study accepted this statement as being valid and subjects were instructed to adhere to the pretest procedures. These procedures are discussed later in the text, on page 22.

RESIDUAL VOLUME

Correction must be made for residual volume when determining body density. The air remaining in the lungs exerts a buoyant force on the body when submerged, thereby making the body weigh less or appear less dense. This eventually results in the calculation of more body fat than is actually present.

Residual volume is the only fractional lung volume which cannot be directly measured with conventional spirometric analysis; it must be determined indirectly. At present, there are two techniques, open or closed circuits, for determining residual lung volume. The open circuit technique most often employed is that of nitrogen washout. This involves the subject's rebreathing of a known volume of pure oxygen. When complete mixing is attained between the gas in the lungs and the oxygen in the rebreathing system, the volumes are analyzed and residual lung volume computed. Closed circuit techniques involve a dilution and eventual equilibration of an inert tracer of indicator gas such as helium, hydrogen, or nitrogen. The nitrogen washout and helium dilution methods are those used most often by current investigators (26,64,65,71,79,90,97,98).

Controversy has arisen as to when and how the determination of residual volume should occur. Studies were conducted in which an average residual volume was used on all subjects in the determination of body density (14,43), but resulted in a high degree of error. Wilmore and Behnke (99) conducted a study in which they estimated residual volume from subjects' vital capacity. They found a low correlation, r = .169, between residual volume and vital capacity.

The results suggested that individual residual volume should be determined when accuracy of body density is essential.

The three to four breath oxygen rebreathing method (44) and the seven minute nitrogen washout method (13,76) have shown success when used in conjunction with underwater weighing. Two other commonly employed determinations of residual volume are Meneely's (64) closed circuit helium dilution technique and the closed circuit nitrogen washout technique, as demonstrated by Buskirk (17) and Lundsgaard-Van Slyke (63).

Several investigators (19,64,71,97) recommend the use of helium in the determination of residual volume because helium diffuses more readily than either oxygen or nitrogen, thereby reducing the error and minimizing the time required for determination. Whether the open or closed circuits are used, the determination of residual volume is time consuming, involves rather elaborate techniques and equipment, and the standard error of measurement remains ± 100 ml (19,66).

FIELD TECHNIQUES FOR ESTIMATION OF BODY COMPOSITION

The determination of body density requires special equipment which is not easily accessible to field studies, therefore, techniques for predicting density have been developed which are more applicable for determining the nutritional status of large numbers of subjects in the non-laboratory setting (52). These techniques include the caliper measurement of skinfold thicknesses, and various anthropometric measures such as diameters, circumferences, and height-weight.

Height-weight Tables

Height-weight tables have been used extensively in the past for the determination of over or under weight. The standard tables proport to give "normal" body weight for an individual based on age, sex, and height (14,20,59,77). They were originally developed by insurance companies based on the relationship between excess weight and mortality. Several investigators believe that assessment of body fat on the basis of height and weight standards is an inadequate and unsound determination (57,82,85,90,104).

Somatotyping

Somatotyping is a method which assesses bone structure and body build (14,16). It involves photographs from three planes of the nude body. A numerical value from one to seven is assigned to the subject's degree of each of the three components of physique; endomorph, mesomorph, and ectomorph. Individuals with a prominant endomorphic physique are characterized by their roundness and softness. Ectomorphic physiques are prominently linear, tall and slim, while mesomorphs lie between the two extreme physiques and constitute muscularity. Research indicates that when compared to density as determined by underwater weighing, somatotyping is not a valid method for determining fatness (14,16).

Anthropometry: Skinfolds, Circumferences, and Diameters

Anthropometry involves the measurement of skinfold thicknesses, circumferences, and diameters. These may be used singularly or in combinations in the form of regression equations to predict body density, and in turn estimate percent body fat.

Skinfold calipers are used to measure the thickness of the double layer skin-plus-fat fold. The estimation of total body fat from skinfold measurements is based on the assumption that subcutaneous fat deposits are indicative of total body fat. Numerous studies have been conducted to determine the validity of using skinfold calipers to measure subcutaneous layers of fat, as well as the use of skinfold measures for determination of total body fat. The Harpenden and Lange calipers are the two most often used to measure the skinfold thickness. Fry (35) found that use of the Harpenden calipers to measure subcutaneous fat layers was an accurate means when validated against surgical incision of the fat layer. Lee (61) found a correlation of r = .84 between skinfold measures recorded with the Harpenden calipers and measures obtained by surgical incision. He observed that the caliper readings of skinfold thicknesses were always greater than the mean actual fat thickness, thereby overestimating the percentage of body fat. Sloan (89) reported no significant difference between skinfold readings with use of the Harpenden or Lange calipers.

Caliper readings of skinfold thicknesses have been validated against other techniques of assessing body composition. Young et al. (104) correlated body weight, oxygen consumption, creatinine excretion, standard weight, and skinfold values to body density as determined by underwater weighing. They concluded that skinfold measures indicated relative fatness better than the other elaborate procedures.

Booth et al. (10) compared skinfold measures obtained by calipers to measures of subcutaneous fat obtained by ultrasound and electrical conductivity. They found that both ultrasound and electrical conductivity produced more accurate measures of subcutanious fat than did caliper determinations, but recommended the use of calipers for practical reasons. Likewise, Garn (39) found a high correlation, r = .88, between soft tissue x-ray measures of the subcutaneous fat layer and measures obtained by calipers. He advised using skinfold calipers due to their ease of application as well as the reduced time and expense involved with their use. Brozek and Keys (14) showed a good relationship between skinfold measurements and underwater weighing in the determination of total body fat. Other investigations are in agreement with these findings (15,17,23,26,28,76,79,90).

The skinfold method has the great merit of simplicity, speed, and minor expense. The limitations of the accuracy in skinfold measures are: 1) improper use of the equipment; 2) improper location of the site; 3) the manner in which the fold is lifted; 4) improper placement of the instrument on the fold; and 5) selection of the appropriate equation for the population involved in the study.

ANTHROPOMETRIC EQUATIONS INVOLVING COLLEGE-AGE WOMEN

Many studies have been conducted in which a large battery of anthrompmetric measures were taken on college-aged females. With the use of regression equations and statistical analysis, formulas have been developed for the determination of body density from select skinfolds, circumferences, diameters, or a combination of these measures. Pollock et al. (79) found that in college women, the highest correlation to body density was with a combination of the three measures. They devised an equation for prediction of percent fat which involved thigh and iliac crest skinfolds, knee diameter, and wrist circumference. An equation involving the thigh and iliac crest skinfolds alone correlated well, r = .775, with density values obtained by underwater weighing, but not as highly as the equation using measures of all three.

Katch and Michale (52) found that in college females, the highest multiple correlation with density was obtained by using the equation involving the iliac crest, tricep, and subscapular skinfolds, and buttock, abdomen, and arm girths.

Young and Blondin (100) calculated body weight in young women from the product of stature, a constant value, and the squared sum of certain "envelope" anthropometric measurement. From this value they assessed body fatness. These results were correlated to values obtained by underwater weighing and the investigators concluded that the method was not applicable for predicting body fatness in young women.

Wilmore and Behnke (99) conducted a study involving college females. They took a battery of anthropometric measures on the subjects and incorporated them into a stepwise linear multiple regression equation. They concluded that when correlated to density values obtained by underwater weighing, that body density could be predicted almost equally well from either skinfolds, circumferences, and diameters, or a combination of them. They formulated three equations. The first involved the tricep, subscapular, and thigh skinfolds. The second included umbilicus, abdomen, buttock, arm, and forearm girths, and the third equation used the subscapular skinfold, knee diameter, neck and umbilicus circumference, as well as the minimum abdominal circumference.

Katch and McArdle's study (51) compared the values obtained by the three equations devised by Wilmore and Behnke (99), the equation by Katch and Michael (52), Sloan's equation (90), as well as the investigator's own equation. Their equation utilized arm, average of two abdomen measures, forearm, and thigh circumferences. The equations were all devised for application on college women, and the purpose of the study was to determine which of the six equations for this population was the most valid predictor of body density. They concluded that their own was the most valid measure.

Durnin and Rahaman (26) conducted a study in which they attempted to formulate simple equations for the prediction of the quantity of fat in the bodies of young women, mean age 21.7 years. They used measures of skinfold, girth, and diameters. The total skinfold thickness correlation with density, as determined by underwater weighing, was -.778. The investigators found that none of the circumferences or diameters gave as high a correlation with density as did skinfolds, thus only skinfolds were used in the equations. They formulated a regression equation for the prediction of body density from a log of the sum of four skinfold measures; bicep, tricep, subscapular, and iliac crest.

Sloan et al. (90) measured skinfolds at five sites and five circumferences on college women. When correlated to density values obtained by underwater weighing, they concluded that the best single predictor of density was the iliac crest skinfold with $r = -.71$. The tricep correlation was of the same order, $r = -.68$. The multiple correlation between the two was -.74, and the addition of other skinfold or girth measurements failed to increase the correlation.

SUMMARY

Many methods for determination of body composition have been employed in various investigations. Of the available laboratory techniques, the method used most widely for determination of body density is underwater weighing. This has been validated quite extensively and has been deemed as reliable.

Height-weight tables have been used a great deal in the past for the assessment of body weight, but research has indicated their use is limited in accuracy.

Research outside the laboratory setting prompted the formation of faster, more convenient equations. These equations involve measures of skinfold thicknesses, circumferences, and diameters, either singularly or in combinations. There are numerous equations available for use today for all age groups, although only those for women 18-22 years of age were discussed.

Chapter 3

PROCEDURES

This chapter includes a description of the following: 1) selection of subjects; 2) testing equipment; 3) pretest protocol; 4) procedures for skinfold measures; 5) underwater weighing and residual volume protocol; and 6) prediction equations examined in this study.

SELECTION OF SUBJECTS

Forty-seven female Kansas State University students volunteered to participate as subjects in this study. Their ages ranged from 18 to 22 years, and weight 101.00 to 162.25 pounds, with mean values being 20.26 years and 125.62 pounds, respectively.

TESTING EQUIPMENT

The equipment used in this study included the following:

1. A full capacity medical balance scale, manufactured by Douglass Homs Corporation, Belmont, California.
2. Lange skinfold calipers, calibrated in mm.
3. Underwater weighing equipment consisted of the following:
   a) The dimensions of the tank were 106 cm wide by 182 cm long by 188 cm deep. The walls of the tank were 15 cm thick and constructed of concrete.
   b) The weighing platform consisted of an aluminum frame with a seat made of plastic chair webbing. The seat

was 49 cm by 89 cm. The platform seat was 92 cm below the upper rim of the tank. The platform rested on four force cube transducers with bonded strain gages.

c) A solid state underwater strain gage scale was used for recording subject's weight while under water.

d) The underwater weighing tank was filled with tap water. The temperature of the water ranged between 33 - 37 ^{o}C. A sump pump was used to empty the tank.

The underwater weighing system at Kansas State University is a modification of the system described by Aker and Buskirk (2).

4. A 13.5 liter Collins Respirometer was used to determine subjects' residual lung volume by the closed circuit helium dilution technique. Additional hosing was added and five pounds of lead weight was attached to them to reduce the buoyancy effect.

5. A kymograph drum and paper recorded subjects' continuous respiratory pattern as well as gas amounts added to the residual volume analyzer.

PRETEST PROTOCOL

Subjects were instructed not to consume any gas forming foods 24 hours prior to their testing time. The intent of this was to avoid excessive gas in the gastrointestinal tract, which would make the subject more buoyant. Subjects were instructed to avoid eating any foods four hours, and no liquids two hours prior to test time. The purpose of this was to insure an as accurate as possible land weight recording.

Immediately prior to the testing time, subjects were instructed to empty bowels and bladders. Subjects' land weight was then recorded to the nearest quarter pound. Subjects wore one piece nylon swim suits throughout the testing procedures. Personal data and skinfold measures were taken and recorded immediately prior to the underwater weighing.

PROCEDURES FOR SKINFOLD MEASURES

Skinfold measurements were taken at five sites on the right side of the body with the Lange skinfold calipers. Consecutive skinfold measures were taken at each site until two readings were in agreement. The thickness of the swim suit material was measured and subtracted from the skinfold reading.

The skinfolds were located and recorded according to the suggestions by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council (51). They were as follows:

1. Tricep - a fold ran parallel to the lenght of the arm, midway between the acromion and olcranon processes on the posterior side of the right arm, with the arm hanging relaxed.

2. Iliac crest - verticle fold on the crest on the ilium at the midaxillary border.

3. Subscapular - inferior angle of the scapula with the fold running parallel to the axillary border.

4. Abdomen - horizontal fold, approximately 5 cm adjacent to the umbillicus.

5. Thigh - verticle fold on the front thigh, midway between the hip and knee joint.

UNDERWATER WEIGHING AND RESIDUAL VOLUME PROTOCOL

The underwater weighing tank was filled at least 30 minutes prior to testing. Water temperature was kept within the 33 - 37° C range. The leaded vest was submerged to allow for complete saturation of the canvas material. Water was allowed to settle as much as possible to free the tank of trapped air bubbles.

Prior to entering the tank, subjects were informed and accustomed to the intent and procedures of the tests. Access to the tank was via an eight foot aluminum ladder. The 11 pound lead vest was fitted on, and the testers manually floated the subject onto the center of the platform, with care taken that the subject was not in contact with the walls of the tank and that the feet were placed on the foot rest to ensure support and stabilization in the water. The noseclip was adjusted and the subject practiced submersion by slowly bending forward and lowering the trunk and head until the water just covered the back of the head.

The residual volume analyzer and support equipment were flushed with room air to remove any helium. Three to five liters of room air was added to the bell. The mouthpiece valve was closed to contain the system. The kymograph was turned on to record a reference line. A known amount of helium, usually 1000 cc BTPS, was added to the bell and recorded. The fan was turned on to completely mix the gases in the system. When equilibration occurred, the percentage of helium in the analyzer was read and recorded. This constituted the first helium reading.

The mouthpiece and weighted hoses were connected to the subject. The blocks were removed from the strain gages, and the tester waited for the subject to submerge.

When ready, the subject exhaled normally, held their breath, turned the valve on the mouthpiece so that they were then connected to the spirometer circuit, and slowly bent forward until completely submerged. The subject held this position while the underwater weight was recorded, and upon the tester's signal, the subject began breathing the gases in the residual volume analyzer and slowly sat up.

The subject remained in a sitting position while breathing air from the analyzer for approximately three minutes. The subject's expired air was circulated through soda lime to remove carbon dioxide. Oxygen was added to the system with the flow being adjusted until the subject's tidal volume tracing on the kymograph maintained a reasonably horizontal line. This rate of oxygen addition was equal to the rate at which carbon dioxide was removed and the purpose was to ensure maintenance of a constant volume of gases in the system. The respiration of the subject was continuously recorded on the kymograph drum. The tester checked the helium meter approximately every 30 seconds and the helium percentage was recorded upon equilibration. The temperature of the gas in the residual volume analyzer was recorded and corrected to BTPS.

The subject was disconnected from the system and manually floated off the weighing platform. The lead vest was removed and placed on the platform. The subject stood quietly, arms down at their sides, while the residual volume analyzer was flushed with room air to remove all helium. The mouthpiece was corked and placed on the platform by the vest. The underwater weighing machine was activated and the weight of the vest and mouthpiece were recorded. This provided a reference line from which to calculate the amount of weight the subject had contributed to the previous recording. The entire procedure was repeated one or two times to ensure accuracy of the subject's underwater weight.

Motley's procedure (71) for determining residual volume was followed in this study. The helium concentration of the gas within the system just before the subject was added, and after they came to equilibrium, constitute the two significant measures upon which the determination of the residual volume was based. The first helium reading minus the second yielded the additional volume which the subject's lungs added to the system. This was the subject's functional residual volume. The buoyancy force that this volume of air exerted was corrected for in determining the subject's density (17).

Residual volume is the amount of air remaining in the lungs at the end of a forced expiration. Because of the difficulty in obtaining a reliable maximal expiration upon underwater weighing, functional residual capacity (FRC) is measured instead of residual volume. The procedures for determination of FRC are as follows:

$$\text{Total volume} = \frac{\text{Helium added in cc}}{\text{First helium meter reading}}$$

$$\text{FRC} = \text{Total volume X } \frac{\text{First He reading - Final He reading}}{\text{Final He reading}}$$

One hundred cc are subtracted from the FRC to compensate for subjects' absorption of helium, and the FRC is then multiplied by the temperature correction BTPS of the gas in the system.

PREDICTION EQUATIONS EXAMINED IN THIS STUDY

The three skinfold equations used for estimating percent body fat in this study were as follows:

1. Sloan (84) conducted a study in which five skinfold measures were correlated with body density as determined by underwater weighing. A multiple correlation of -.74 was found to be the best predictor of body density. The tricep and iliac crest measures yielded this value in the equation.

$$D = 1.0764 - 0.00081 \text{ (iliac)} - 0.00088 \text{ (tricep)}$$

Density was used to estimate percent body fat using Brozek's equation (15).

$$\text{Fat\%} = (4.57/D - 4.142)\ 100$$

2. Pollock et al. (79) developed an equation involving two skinfold measures, iliac crest and thigh, to determine body density of young women.

$$D = 1.0852 - 0.0008 \text{ (iliac)} - 0.0011 \text{ (thigh)}$$

Siri's formula (86) was used to calculate percent fat from the density value the equation arrived at.

$$\text{Fat\%} = (4.950/D = 4.50)\ 100$$

3. Pollock and Jackson constructed tables which directly give percent fat based on the sums of skinfold measurements and age. The

actual equations are unavailable. This study employed the sum of three skinfolds, those being thigh, abdomen, and tricep, for women 18-22 years of age. The conversion tables can be found in Appendix C. At the time of this writing, the source of this skinfold technique is unpublished. It is currently in press and will appear in the forthcoming second edition of *The Y's Way to Physical Fitness*.

Chapter 4

RESULTS AND DISCUSSION

This chapter includes the results of the data analysis, their interpretation, and a discussion of their implications.

DATA ANALYSIS AND INTERPRETATION

Appendix A lists the raw data of the 47 subjects for age, land weight, and tricep, subscapular, iliac crest, abdomen, and thigh skinfold measures. Each subject's percentage of body fat as determined by underwater weighing, percentage fat values computed from the three skinfold equations, and the difference between each subject's percent fat as determined by the skinfold equations and the values obtained with the underwater weighing method are listed in Appendix B. When percent body fat obtained by the underwater weighing method is refered to, the expression "%F water" will be its term.

The sum of the tricep, iliac, and abdomen skinfold measurements are used in the YMCA skinfold equation for predicting percent body fat. The Sloan equation includes measurements of two sites, tricep and iliac. In the Pollock method, the iliac and thigh skinfold sites are used in the estimation of percent body fat. The YMCA equation overestimated the percent fat value obtained by underwater weighing on 30 of 47 occasions, Sloan was over 29 out of 47 times, and Pollock overestimated percent body fat 34 out of 47 times.

Table 1

Mean, Standard Deviation, and Range of Body Composition Measures of 47 Females

Variable	M	SD	Range
age, yr.	20.260	1.150	18.0 - 22.0
wt., lb.	125.620	14.650	101.0 - 162.25
LBM, lb	100.390	13.330	75.3 - 141.88
density, g/ml	1.053	.015	1.019 - 1.072
tricep, mm	13.72	3.29	7.5 - 26.0
subscapular, mm	17.51	3.74	11.0 - 25.0
iliac, mm	15.86	3.61	8.0 - 26.0
abdomen, mm	14.28	3.62	7.5 - 25.0
thigh, mm	24.63	4.08	15.0 - 34.0
%F water	19.99	6.22	12.09 - 34.47
%F YMCA	20.83	2.87	15.30 - 28.80
%F Sloan	20.44	2.26	16.12 - 28.09
%F Pollock	23.51	2.65	17.73 - 30.07

The mean values and the standard deviations for all measurements and estimation equations were calculated and are listed in Table 1. The tricep skinfold measure had the smallest mean thickness of all the skinfold sites and had the smallest standard deviation. The range of the tricep skinfold measures were 18.5 mm, second only to the thigh measures which had 19.0 mm difference between the highest and lowest recordings. The thigh skinfold had the largest mean thickness, and the largest standard deviation. The skinfold site with the least variation in thickness was that of the subscapular fold.

The lowest mean percentage of body fat was 19.99% and was determined by the underwater weighing method. Previous work in body composition has shown underwater weighing, with corrected residual volume lift, to be a valid technique for determining body density (8,15,56,99). Body density has been shown to be an excellent indicator of the composition of the body (81,86), therefore, it was assumed that body density and percent body fat as determined by the underwater weigning method was valid.

All measurements and estimation equations were related to body density and percent body fat as determined by underwater weighing, thereby making underwater weighing values the standard. The mean percentages of body fat, as reported by YMCA, Sloan, and Pollock equations, were 20.83%, 20.44%, and 23.51%, respectively. The three estimation equations predicted mean values of percent fat of up to 3.5% above %F water values. Table 2 shows the mean difference between %F water and the three skinfold equations.

Table 2

Mean and Standard Deviation of the Differences Between %F Water and Values Obtained with the Three Skinfold Equations

Equation	Mean	S.D.
YMCA	- 0.841 %	5.55 %
SLOAN	- 0.448 %	5.50 %
POLLOCK	- 3.518 %	5.46 %

As can be seen in Table 2, the Pollock equation overestimated %F water by 3.518%. The mean difference in the Pollock equation was considerable higher than that predicted by the other two equations, yet all three equations had very similar standard deviations of the means. When examining the standard deviations of each of the prediction equations, it can be seen that there was no statistically significant difference in the percent body fat values obtained with any of the three equations.

Table 3 represents the mean variance in values of percent body fat as estimated by the three skinfold equations. This table further indicates the degree to which the Pollock equation appeared to overestimate %F water, although this overprediction was not statistically significant.

Table 3

Mean Minimal and Maximal Values of the Difference Between %F Water and Each Equation

Equation	Minimum	Maximum	Variance
YMCA	- 9.71 %	13.11 %	22.82
SLOAN	- 9.45 %	12.33 %	21.78
POLLOCK	- 12.24 %	10.07 %	22.31

The correlation coefficients between the three skinfold equations and %F water are listed in Table 4. The results show a low relationship between the percent fat value estimated by the skinfold equations and %F water, thereby indicating a large standard error. The r values were expected to be higher, as those reported in the original studies.

Table 4

Correlation Coefficients Between %F Water and the Three Equations

Equation	r value
YMCA	.453
SLOAN	.482
POLLOCK	.485

Table 5 is a comparison of the r values reported in this study and the r values of the prediction equations as originally reported by the investigators who formulated them. The original investigators reported much higher correlation coefficients than were found in this study.

Table 5

Comparison of Present and Original Correlation Coefficients of Skinfold Equations

Equation	Original	Present
YMCA	*	.453
SLOAN	- .740	.482
POLLOCK	- .775	.485

*data not available

Table 6 presents the correlation matrix between all determinations of percent body fat that were used in this study.

Table 6

Correlation Matrix Between Four Determinations of Percent Body Fat

	POLLOCK	SLOAN	YMCA	%F WATER
%F Water	.485	.482	.453	1.000
YMCA	.771	.887	1.000	
SLOAN	.693	1.000		
POLLOCK	1.000			

The highest correlation among any two variables occurred between percent body fat values obtained by the YMCA and Sloan equations. The lowest correlation was between the Pollock and Sloan equations. Individual measurements were also correlated to percent fat values as determined by underwater weighing. Table 7 lists the correlation coefficients among %F water and these measures. In the computation of the skinfold measurements into the equations, the use of more than one measure did not significantly increase the predictability of the methods. For example, the Sloan equation involved the use of tricep and iliac skinfolds. The correlation coefficient for the Sloan equation as determined in this study was r = .482, while the r value of the tricep skinfold site alone was r = .471. The addition of the iliac skinfold measure did not significantly increase the predictability of the Sloan equation, indicating that the tricep measurement alone was sufficient in predicting percent body fat in young women. It is interesting to note that the subscapular skinfold correlated with %F water higher, r = .527, than did any other three skinfold equations, indicating that singularly it could estimate percent fat with greater reliability than the YMCA, Sloan, or Pollock skinfold equations.

Table 7

Corrleation Between Individual Measures
and %F Water

Individual Measure	%F Water
Land Weight	.134
Lean Body Mass	- .490
Total Body Fat	.939
Tricep	.471
Subscapular	.527
Iliac Crest	.430
Abdomen	.257
Thigh	.352

The data obtained in this study was compared to that reported in the literature by previous investigators. All studies were conducted on college age women, and for this reason, one would expect the results of this study to be similar to that reported previously. Table 8 shows the body composition data of seven earlier studies.

Table 8

Comparison of Body Composition Data with Previously Reported Values for Young Women

Study	N	Age yrs.	Weight kg.	Density	%F	LBM kg.
Sloan (90)	50	20.2	55.5	1.047	22.40	43.1
Young (103)	94	20.4	59.0	1.034	27.20	42.7
Pollock (79)	83	20.2	57.5	1.043	24.80	43.0
Katch and Michael (52)	64	19-23	58.4	1.049	21.50	45.8
Wilmore and Behnke (99)	128	21.4	58.6	1.041	25.00	43.9
Katch and McArdle (51)	69	20.3	59.0	1.039	25.60	44.0
Present	47	20.3	57.2	1.052	19.99	45.7

This table indicates subject values on all variables reported in the present study were comparable to those reported by other investigations.

Table 9 is a comparison of mean skinfold thicknesses obtained in this study and those reported in the literature for subjects of similar age and sex. The mean skinfold measures from this study were comparable to those reported by four other investigators. This study did report a slightly higher mean subscapular skinfold than did other studies, and the mean thigh value was slightly lower than the other thigh measures.

Table 9

Comparison of Mean Skinfold Measures as Reported by Five Investigators

Study	tri.	scap.	iliac	abd.	thigh
Wilmore and Behnke (99)	12.81	13.23	17.20	15.00	31.78
Katch and Michael (52)	12.31	10.81	16.49	15.19	-----
Sloan (90)	16.08	-----	19,16	19.40	26.40
Pollock (79)	18.08	15.30	15.30	22.80	28.80
Present	13.72	17.51	15.86	14.28	24.63

DISCUSSION

The correlation coefficients obtained in this study were lower than expected. The highest correlation reported in the present study was that between %F water and the Pollock equation, r = .485. Pollock et al (79) originally reported a correlation of r = .775 between values of percent body fat obtained by this equation and values obtained by underwater weighing. Sloan et al. (90) demonstrated a correlation of r = -.740 when they formulated their equation on college women. The r value obtained for this equation in the present study was r = .482. The original correlation coefficient for the YMCA equation was not available, but this study determined it to be r = .453.

Possible explanations for the low correlation coefficients found in the present study were explored. The literature indicates that the underwater weighing determination of body density is a valid measure of the composition of the body (8,56,81). A good relationship exists in the determination of percent body fat between skinfold predicted values and underwater weighing values (14,17,28,56,79). Therefore, the error precipitating the low correlation coefficients does not stem from the design of the present study.

The major source of error in determining body density originates in the inaccurate estimates of the air remaining in the lungs at the time of the underwater weighing (44). Upon occasion, difficulties were experienced in the residual volume analyzing equipment during the experiment. Keys and Brozek (14) have shown that for a 70 kg man with 20% body fat, an error of ±100 ml. in the residual volume measurement would correspond to an error in the estimation of body fat of approximately ±0.8% of the body weight. This indicates that the possible errors in the determination of residual volume in this study could not have caused the low correlation coefficients that were found to exist.

Table 9 examined the mean skinfold measures obtained in this study and those reported by previous investigators (52,79,90,99). Skinfold measures at all sites in the present study showed a great degree of commonality with those reported earlier, therefore, the source of error does not stem from the skinfold measurements of the present study.

Table 8 examined the data reported by previous investigators (51,52,79,90,99,103) to determine whether the mean subject data of this study varied extensively from those reported in the literature and in the original studies. No obvious differences were found in the mean values, although if the range of the data were examined, discrepancies would have surfaced. It was determined that the low correlation coefficients reported in this study stemmed from the subject population. The subject population in the present study demonstrated very little variation in regards to land weight, lean body mass, total body fat, and percent body fat. If this study had a more representative population within the age limits of 18-22 years, the correlation coefficients would have been higher. Selection of extreme body types, both very lean and very fat, was needed to produce accurate correlation coefficients. As it was, the little variation in the subject population caused the correlation coefficients to be low.

The purpose of this study was to determine which of three skinfold estimation equations, Sloan, YMCA, and Pollock, were the most valid predictor of percent body fat in college females. The results of the data analysis indicate that there was no statistically significant difference between the percent body fat values obtained with the three equations. It initially appeared that the Sloan equation would be the most valid predictor for the mean difference between values obtained by this equation and percent fat values as determined by underwater weighing was -.448%. The mean Sloan predicted value of percent fat was overestimating the %F water values by .448%. The YMCA equation, employing the sum of three skinfold measures, appeared to be the second best predictor of percent body fat of the equations in question. This equation overestimated %F water values by .841%. The Pollock equation overpredicted percent fat by 3.51%. The standard deviations of the YMCA, Sloan, and Pollock equations were similar, being 5.55%, 5.50%, and 5.46%, respectively. This indicates that there is no significant difference in the values of percent body fat obtained by any of the three estimation equations, therefore, no on equation can be said to be more valid than the other two.

Chapter 5

SUMMARY AND CONCLUSIONS

This chapter includes a summary of the purpose, findings, conclusions of the study, and recommendations for future research based on this study.

SUMMARY

The purpose of this study was to determine the validity of three skinfold equations used to estimate percent body fat in young women by comparing their predicted values to percent fat values obtained by the underwater weighing method. The study was conducted at Kansas State University during the spring semester, 1980. Subjects were 47 volunteer female students, ages 18-22 years. Each subject was weighed underwater to determine body density and percent body fat. Five skinfold thicknesses were measured on each subject with a Lange caliper. Percent body fat was estimated by three separate skinfold equations and compared with values obtained by underwater weighing to determine validity. Based on the data analysis, it was determined that there was no significant difference in the percent body fat values obtained by the three skinfold equations.

Correlation coeffients were computed among all measurements. The YMCA, Sloan, and Pollock skinfold equations showed low correlations with percent body fat values as determined by underwater weighing. The correlations were $r = .453$, $r = .482$, and $r = .485$, respectively. Correlation coefficients were lower than expected due to errors in the selection of subjects.

RECOMMENDATIONS BASED ON THIS STUDY

It is recommended that further research is necessary with certain adaptations to the study. The study should be repeated under the following conditions:

1. Future studies should select subjects representing a wider range of the population, including the extremes as well as the average population.

2. Future studies should consider data collection on a larger number of subjects within the appropriate population.

3. Formulation of multiple regression models to develop predictions of body density from the infependent variables could be incorporated into future research.

4. Estimation equations involving anthropometric measures other than skinfolds could be included in future studies.

5. Future studies should perform both the underwater testing procedures and the measurement of skinfold thicknesses on two separate occasions to ensure the reliability of the measures.

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APPENDIX A

RAW DATA

	Age	Land Weight	Tricep	Sub-scapular	Iliac	Abdomen	Thigh
1	21	121.00	13.0	21.0	14.0	17.0	30.5
2	21	121.00	12.0	17.0	16.0	12.0	23.0
3	22	112.50	12.0	13.5	11.0	12.0	22.0
4	21	136.25	10.0	15.0	16.0	17.0	27.0
5	19	162.25	17.0	17.5	17.0	13.0	23.0
6	20	146.75	16.0	19.0	21.0	18.0	23.5
7	21	129.00	14.0	17.0	17.0	13.0	28.0
8	22	129.00	16.0	21.0	18.5	11.5	32.0
9	21	121.00	12.0	13.0	13.0	10.0	15.0
10	21	140.00	18.0	21.0	22.0	18.0	22.0
11	20	113.50	17.0	25.0	16.0	19.0	30.5
12	18	130.75	13.0	18.0	16.0	19.0	25.0
13	18	137.50	16.0	20.0	17.0	8.0	27.0
14	19	111.75	11.0	11.0	11.0	13.5	21.0
15	18	122.75	18.0	15.0	17.0	13.0	21.5
16	20	133.75	11.0	13.0	13.0	19.0	26.5
17	20	148.25	13.5	16.0	18.0	14.0	19.5
18	22	142.75	14.0	17.0	20.0	12.5	18.0
19	20	101.00	16.5	23.0	15.0	13.0	26.0
20	20	108.00	11.0	15.5	15.0	12.0	24.0
21	20	104.50	10.0	13.5	15.0	14.0	24.0
22	21	112.00	15.0	15.0	16.0	10.0	27.0
23	19	118.75	7.5	17.5	13.0	16.0	23.0
24	21	127.50	13.0	19.0	14.0	15.0	22.0
25	21	130.75	11.0	14.0	12.0	23.0	22.0
26	22	135.00	18.5	18.0	26.0	13.0	24.0
27	20	122.50	15.0	20.5	16.0	17.0	28.0
28	20	151.75	16.2	23.0	16.5	14.0	27.0
29	20	129.50	12.0	23.0	18.0	16.0	31.0
30	22	107.25	11.0	16.0	14.0	7.5	28.5
31	20	116.25	11.0	12.0	11.0	14.0	21.0
32	19	108.75	12.0	20.0	17.0	13.0	24.0
33	20	133.00	11.5	13.0	13.0	10.5	16.0
34	20	123.25	10.0	12.0	12.0	13.5	18.0
35	21	114.00	11.0	19.0	15.5	13.0	24.0
36	21	159.50	17.0	25.0	14.0	12.0	34.0
37	21	111.75	13.0	21.0	17.0	21.0	27.0
38	22	128.50	19.0	21.0	23.0	13.0	27.0
39	18	112.25	12.0	16.0	12.0	17.0	22.0
40	20	118.50	14.0	18.5	15.0	13.0	22.5
41	19	120.25	11.5	16.0	16.0	25.0	23.5
42	20	142.00	26.0	25.0	25.0	12.0	31.0
43	20	125.75	13.0	13.0	13.0	10.0	23.0
44	19	138.75	12.0	20.0	13.0	17.0	24.0
45	19	128.50	15.5	15.0	18.0	10.0	28.0
46	21	114.00	9.0	14.5	8.0	13.0	28.0
47	22	101.50	15.0	14.0	19.0	14.0	23.0

APPENDIX B

DETERMINATION OF PERCENT FAT AND DIFFERENCES BETWEEN THE ESTIMATIONS AND %F WATER VALUES

	%F WATER	%F YMCA	%F SLOAN	%F POLLOCK	DIFF YMCA	DIFF SLOAN	DIFF POLLOCK
1	16.80	22.70	19.54	25.76	- 5.81	- 2.65	- 8.87
2	14.62	20.30	19.85	22.73	- 5.65	- 5.23	- 8.14
3	30.51	17.40	18.18	20.44	13.11	12.33	10.07
4	12.44	21.20	19.12	24.73	- 8.76	- 6.68	-12.30
5	12.56	21.10	22.01	23.10	- 8.54	- 9.45	-10.54
6	14.49	24.20	23.00	24.80	- 9.71	- 8.50	-10.31
7	20.56	20.90	21.09	25.60	- 0.34	- 0.53	- 5.04
8	24.80	22.10	22.15	28.17	2.70	2.65	- 3.37
9	18.17	17.20	18.85	17.73	0.97	- 0.68	0.44
10	29.63	25.10	24.07	24.41	4.53	5.56	5.23
11	27.73	23.30	21.85	26.49	4.43	5.89	1.24
12	13.35	22.70	20.22	23.73	- 9.35	- 6.86	-10.38
13	15.23	23.60	21.64	25.09	- 8.37	- 6.41	- 9.86
14	12.52	15.30	18.00	19.95	- 2.78	- 5.84	- 7.43
15	18.13	20.45	22.56	22.35	- 2.32	- 4.43	- 4.22
16	18.76	19.30	18.39	23.40	- 0.54	0.27	- 4.63
17	18.76	22.10	21.06	21.72	- 3.34	- 2.30	- 2.96
18	14.47	22.10	21.92	21.70	- 7.63	- 7.45	- 7.23
19	20.18	22.00	21.15	23.87	- 1.82	- 0.97	- 3.69
20	20.73	19.85	19.15	22.87	0.88	1.58	- 2.14
21	16.30	28.75	18.79	22.87	- 2.45	- 2.49	- 6.57
22	17.80	20.30	20.94	24.73	- 2.50	- 3.14	- 6.93
23	14.15	18.75	17.23	21.65	- 4.60	- 3.08	- 7.50
24	19.14	21.50	19.54	21.52	- 2.36	- 0.40	- 2.38
25	17.87	18.90	18.16	20.80	- 1.03	- 0.29	- 2.93
26	34.47	26.70	25.62	26.88	7.77	8,85	7.59
27	30.46	21.65	20.94	25.23	8.81	9,52	5.23
28	28.26	23.75	21.47	24.91	4.51	6.79	3.35
29	28.35	23.30	20.52	27.48	5.05	7.83	0.87
30	13.82	20.00	18.82	24.75	- 6.18	- 4.50	-10.93
31	22.67	15.45	18.00	19.95	7.22	4.67	2.72
32	28.77	21.00	20.18	23.59	7.77	8.59	5.18
33	14.98	28.30	18.67	18.22	- 3.32	- 3.69	- 3.24
34	12.09	26.70	17.80	18.84	- 4.61	- 5.70	- 6.75
35	19.61	27.90	19.32	23.05	1.71	0.29	- 3.44
36	31.48	22.40	21.00	27.52	9.08	10.48	3.96
37	23.46	28.60	20.55	25.09	4.86	2.91	- 1.63
38	28.74	26.20	24.78	27.29	2.54	3.96	1.45
39	13.75	18.90	18.52	20.80	- 5.15	- 4.77	- 7.05
40	21.49	22.00	20.24	22.13	- 0.51	1.25	- 0.64
41	15.25	20.30	19.67	22.98	- 5.05	- 4.42	- 7.73
42	23.95	28.80	28.06	30.07	- 4.85	- 4.14	- 6.12
43	15.42	17.90	19.21	21.65	- 2.48	- 3.79	- 6.23
44	17.77	29.70	18.85	22.15	- 1.93	- 1.08	- 4.38
45	16.47	21.80	21.79	25.96	- 5.33	- 5.32	- 9.49
46	12.69	16.05	16.12	22.33	- 3.36	- 3.43	- 9.64
47	25.82	20.60	21.95	23.82	5.22	3.87	2.00

APPENDIX C

YMCA - SUM OF
THREE SKINFOLDS
WOMEN 18-22 YEARS

SUM	%F	SUM	%F	SUM	%F
13	8.6	47	20.9	81	30.2
14	9.2	48	21.2	82	30.5
15	9.6	49	21.5	83	30.7
16	10.0	50	21.8	84	30.9
17	10.3	51	22.1	85	31.2
18	10.7	52	22.4	86	31.4
19	11.1	53	22.7	87	31.6
20	11.5	54	23.0	88	31.8
21	11.9	55	23.3	89	32.0
22	12.2	56	23.6	90	32.2
23	12.6	57	23.9	91	32.4
24	13.0	58	24.2	92	32.6
25	13.4	59	24.5	93	32.8
26	13.8	60	24.8	94	33.0
27	14.1	61	25.1	95	33.2
28	14.5	62	25.4	96	33.4
29	14.9	63	25.7	97	33.6
30	15.3	64	36.0	98	33.8
31	15.6	65	26.2	99	34.0
32	15.9	66	26.5	100	34.2
33	16.2	67	26.7	101	34.4
34	16.5	68	27.0	102	34.6
35	16.9	69	27.3	103	34.8
36	17.2	70	27.5	104	35.0
37	17.6	71	27.8	105	35.2
38	17.9	72	28.0	106	35.4
39	18.3	73	28.3	107	35.5
40	18.6	74	28.6	108	35.7
41	18.9	75	28.8	109	35.9
42	19.3	76	29.1	110	36.0
43	19.7	77	29.3	111	36.1
44	20.0	78	29.6	112	36.3
45	20.3	79	29.8	113	36.5
46	20.6	80	30.0	114	36.6

APPENDIX D

CONSENT FORM

Kansas State University

Investigators: Todd Rohr and Nancy Hensler
Department of HPER (phone 532-6240)
Advisor: Dr. W.B. Zuti

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 skinfold measures 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 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 a bathtub. Research assistants will be used and they will be 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	______________________________ signature

UNDERWATER WEIGHING VALIDATION OF THREE SKINFOLD ESTIMATION TECHNIQUES FOR USE ON COLLEGE FEMALES

by

NANCY L. HENSLER

B. S., East Stroudsburg State College, 1978

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Health, Physical Education and Recreation

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

The purpose of this study was to determine the validity of three skinfold equations used to estimate percent body fat in young women by comparing their predicted values to percent body fat values obtained by the underwater weighing method. The study was conducted at Kansas State University during the spring semester, 1980. Subjects were 47 volunteer female students ages 18-22 years. Each subject was weighed underwater to determine body density and percent body fat. Five skinfold thicknesses were measured on each subject with a Lange caliper. Percent body fat was estimated by three separate skinfold equations and compared with values obtained by underwater weighing to determine validity. Based on the data analysis, it was determined that therw was no statistically significant difference in the percent body fat values obtained by the three skinfold estimation equations.