A DESCRIPTIVE AND NORMATIVE STUDY OF
THE BODY COMPOSITION CHARACTERISTICS
OF THE NON-ATHLETE FEMALE POPULATION

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in
Physical Education.

by

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DEDICATION

This thesis is dedicated to my husband and best friend Tim Tobin for his love, encouragement, and patience. I would also like to dedicate this work to my parents, Wilfred and Natalie Mathewson, whose love, guidance, and support made my education a reality.
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ABSTRACT

A DESCRIPTIVE AND NORMATIVE STUDY OF
THE BODY COMPOSITION CHARACTERISTICS
OF THE NON-ATHLETE FEMALE POPULATION

by

Robin Mathewson Tobin

Master of Arts in Physical Education

The purpose of this study was to determine the percent body fat norms of non-athlete women ages 22-62 years. Additional information sought was the predictive value of skinfold and circumference measurements, as well as the influence of the menstrual cycle on densitometric measurements.

Fifty-three women ages 22 to 62 participated in the study. The subjects were categorized into age group decades of 30-39, 40-49, and 50-59, with an additional grouping 22-62 years encompassing all subjects. Height, weight, vital capacity, and percentage of body fat by hydrostatic weighing, Allen's ten, Yuhasz's six, and Durnin's four skinfolds, as well as McArdle's three circumferences were determined for each subject. Skinfold measurements
included right vertical, left vertical, and right horizontal readings. In addition, ten subjects were retested after two weeks to determine the influence of the menstrual cycle on percent fat estimations, and nine subjects were retested one month later to determine the reliability of laboratory methods.

The major findings of this study were:

1. The average weight and densitometric percent body fat figures were: 30-39 years, 126.92 pounds and 28.10% fat; 40-49 years, 128.05 pounds and 30.75% fat; 50-59 years, 134.57 pounds and 36.24% fat.

2. For all age groups with the exception of the fourth decade, the only protocol which predicted percent fat with no significant difference from hydrostatically determined percent fat was that of Durnin.

3. When testing the predictive value of the thirteen individual skinfold sites, it was found that for each age group, 30-39, 40-49, 50-59, and 22-62, a different combination of sites with corresponding regression formula was most predictive.

4. There were no significant differences between the percent fat values obtained by right and left vertical skinfolds, not between right vertical and horizontal skinfolds.

5. There were no significant differences between the percent fat values obtained on the seventh and twenty-first days of the menstrual cycle.
It was concluded that variably determined percent body fat increases with age, and that adipose proportions are specifically modified with age.
CHAPTER I

Introduction

Traditionally, the primary source referred to in judging a person's body composition has been age-height-weight tables, based upon standards developed from life insurance actuary statistics (The Association and Actuarial Society of America, 1912). These standards make gross assumptions concerning proportions of fat and muscle mass, and the quality of body composition as it relates to total body size. Therefore such standards provide a very large margin for error in estimating true body composition.

Accurate laboratory appraisal of body composition, permitting quantification of the major structural components of the body (muscle, bone, and fat) can be accomplished in several ways. Reliable and valid methods available for this purpose include radioactive potassium forty counting ($K_{40}$), total body water (deuterium oxide), and densitometry. It is generally agreed by physical anthropologists and exercise physiologists that densitometry is the preferred and practical method for body composition analysis of large populations (Behnke & Wilmore, 1974). Lacking is a set of precise norms derived by systematic densitometric evaluation of representative samples from specific age and sex populations.
Importance of the Study

The need for valid age and sex body composition standards is well documented (Holland, 1980). First and foremost, they would be of value in the formulation of a clinical definition of obesity. It is now accepted that overweight and overfat are not the same, and better body composition standards can be a valuable aid in making this clinical distinction. Need for these standards is well illustrated by the dilemma many athletes face. An athlete may weigh much more than the "average" person for his or her height and weight, although this "extra" weight may be valuable additional muscle mass. Such an athlete may be required to meet a certain weight standard based on height-weight charts to qualify for a particular team sport. In such instances the athlete with great potential strength may be denied participation in competition or forced to lose valuable muscle mass (Moore, 1980).

Another use for precise densitometric body composition norms would be improved reliability comparison with other laboratory measurement techniques. The three previously mentioned techniques are accurate but not always practical, especially in large scale field testing. If it is necessary to utilize less precise anthropometric or skinfold measurements, the resulting data could best be compared and interpreted with comprehensive densitometric age and sex standards.
More precise and comprehensive body composition norms would be most useful to life insurance actuaries, military services for screening of overweight and underweight recruits, and physical education instructors and coaches as one important physiological fitness baseline.

The main purpose of the present study is to develop body composition data for a portion of the population for which there are limited normative standards (Holland, 1980). The population studied included female non-athletes ages thirty through fifty-nine.

Statement of the Problem

Due to limited body composition data for the adult female population there are no valid experimental or clinical percent fat standards. The present study addresses the need for average percent body fat standards for the female non-athlete categorized by age decades.

Hypothesis

Differences in densitometrically determined percent body fat of adult females will not vary by age decades more than ± three percent.

Objectives

1. To determine normative values of percent body fat for non-athletic females by age decade.

2. To compare densitometrically determined percent body fat with various skinfold and circumferential estimations of body composition.
3. To compare selected skinfold values obtained from the right and left sides of the body.

4. To compare selected vertical skinfold values with horizontal skinfold values obtained from the same anatomical site.

5. To compare densitometrically determined values at two different points in the adult menstrual cycle.

Limitations

The predictive equation developed for hydrostatic weighing is based on a normal population. Although the equation has been applied to many "abnormal" populations, recent research indicates this may be inappropriate; such as extremely lean or obese individuals and anorectics (Moe, 1981).

The accuracy of hydrostatic measurement is dependent upon the valid measurement of residual lung volume, the presence of a post absorptive state (Girandola, Wiswell, & Romero, 1977), the absence of prior exercise on the day of testing (Thomas, Etheridge, Londeree, & Shannon, 1979), and the stage of the menstrual cycle (Pollock, Laughridge, Coleman, Linnerud, & Jackson, 1975; Rich & Scherer, 1980).

Delimitations

Directions were given subjects as to the post absorptive state and abstinence from exercising on the day of testing. A questionnaire was used to ascertain whether or not subjects followed these directions, but there was no objective way to determine the true compliance rate.
Testing was done on approximately the eighth or twenty-first day of the menstrual cycle but varied as much as three days with individual subjects.

**Definition of Terms**

*Anthropometric* - Descriptive measurements of the external body form.

*Bimetric (two-diameter)* - Lateral dimensions of the skeletal frame (Holland, 1980).

*Perimetric* - Girth or circumferential measurements of a body segment (Holland, 1980).

*Densitometry (Hydrostatic Weighing)* - An underwater weight measurement which provides body density and specific gravity values. This technique is based on the knowledge that fat tissue is less dense than other tissue (deVries, 1980).

*Total Body Water* - Based on the principle that the proportion of lean body mass which is water is constant at approximately 72%. Deuterium oxide or heavy water is ingested and the proportionate amount excreted is used as a basis for the calculation of total body water (deVries, 1980).

*Potassium Forty Counting (K40)* - Based on the assumption that a constant relationship exists between body potassium and lean body mass (Myhre & Kessler, 1966). By measuring total body water, total body potassium, or body density, it is possible to determine the proportion of
the body composed of fat free mass (Wormersley, Durnin, Boddy, & Mahaffy, 1976).

Helium Dilution - A direct measurement of residual lung volume. The subject breathes a known helium mixture in a closed circuit system. The functional residual lung volume is computed from the dilution of the original helium mixture (McArdle, Katch, & Katch, 1981).

Oxygen Dilution - The functional residual lung volume is determined from the dilution of the lungs' nitrogen concentration with the breathing of a known volume of oxygen (McArdle, et al., 1981).

The remainder of this thesis will be organized into four chapters: a review of the related literature, the research methodology and design, analysis of the data, and a summary and conclusions.
CHAPTER II

Review of the Literature

In 1953, Brozek, Pei Chen, Carlson, and Bronczyk hydrostatically weighed women in three different age groups, 18-29 (n = 23), 31-45 (n = 19), and 46-67 (n = 20), to assess age and body fat differences. There was incomplete information on study details, such as the specific formula used to calculate percent fat, and whether menstrual cycle stage was considered. The reported specific gravities were: age 20 through 29 averaged 1.0459, ages 30 through 39 averaged 1.0336, and women in their late forties and fifties were 1.0218. Although the results of this study were limited they precluded a trend seen in many later investigations.

A 1953 study by Chen evaluated body fat in 65 American women ranging in age from 18 to 60 years. The women were healthy volunteers of typical "female type" occupations such as housewife, nurse, and secretary. They were hydrostatically weighed and the specific gravity figures were converted to percent fat using the formula developed by Rathbun and Pace (1954). The values reported for percent body fat of these women in age groups 18-30, 30-45, and over 46 were 26.11%, 32.39%, and 38.31% respectively.
In a large scale study conducted in 1961, Young, Martin, Chihan, McCarthy, Maniello, Harmuth, and Fryer hydrostatically tested 94 young women ages 17-27, from a New York university community. This study controlled menstrual influence by not conducting underwater weighings ten days prior to, or during menstruation.

Although the ages of the subjects in the above study ranged from 17-27, the mean age was a low 20.36. Mean percent body fat was 28.69 with a range of 15.81% to 38.62% using the formula of Rathbun and Pace (1945). When Siri's (1956) percent formula was applied the figures were slightly higher.

Two years later Young teamed with Blodin, Tensuan, and Fryer (1963) to expand the study of body composition to somewhat older adult females. The subjects were 88 normal women ranging in age from 30-70 years. The significant change in fat mass was noticed after age 40. The 30-40 age group had a mean percent fat very similar to the 26-30 group studied earlier, but with a larger standard deviation. The percent fat values then rose with each decade as follows: 40-49, 35%; 50-59, 42%; and 60-69; 45%.

Another study of young women (17-25 years of age) by Sloan, Burt, and Blyth (1962) also weighed subjects underwater to determine body composition. Subjects were 50 healthy female students in North Carolina. Residual volume was determined after the weighing by an open circuit
nitrogen dilution process, and percent fat was calculated utilizing the formula of Siri (1956).

The average percent body fat of 22.91 (Siri's formula, 1956) reported for the whole group of the above study was the lowest of any prior densitometric studies for the age group 18-60 years. The percent fat value range was 13-37. Using the formula of Rathbun and Pace (1945) the mean was 22.13% and the range was 11.70% to 37.40%, representing slightly lower figures than those computed by the Siri equation (Siri, 1956).

Another study of California female college subjects was reported by Katch and Michael (1968). The 50 women ranged in age from 19-23 years and were hydrostatically weighed in the prone position, with the residual volume measurement in the same position via the helium dilution method. The percent fat was determined using Brozek's formula (Brozek, Grande, Anderson, & Keys, 1963). The average lean body weight for this group was 45.8 kg while the average percent body fat was 21.5. These appear to be somewhat low figures and may reflect the geographic specificity of the sample population.

In 1969, Wilmore compared different values for residual volume, as part of a densitometric study of 128 California college women averaging 21.4 years. The closed circuit oxygen dilution method was used to measure residual volume. The mean weight of this group was 58.58 kg and the mean percent body fat was 25.73. Since residual volume is
an important aspect of hydrostatic weighing calculations, it is important to note that when a constant value for volume was used (1000 ml) the percent body fat was 25.71, and when a fraction of the vital capacity was used (.28) the percent fat was 25.80. Although these fat figures correlate highly, caution should be taken in assuming this is always the case, because factors such as age, sex, and pulmonary disorders can produce considerable variation in residual volumes (Wilmore, 1969).

In 1973, Katch and McArdle investigated the prediction of body density from skinfold and circumference measures with hydrostatically determined density of 69 New York college women. Residual volume was determined by oxygen dilution prior to submersion, and Brozek's (1963) percent fat equation was used. The average mass of these women was 59 kg and the average percent fat was a relative low 20.3 with a standard deviation of only 1.8%. A possible reason for the relatively low percent fat may be that all subjects were volunteer physical education activity students.

A study of 272 women by Durnin and Womersley (1974) was designed with the intent to assess the validity of skinfolds to predict body composition as compared with hydrostatic measurement. Residual volume was determined at the moment of the weighing by nitrogen dilution, and Siri's (1956) equation was used for the percent fat calculations.

The women were divided into various age groups for body fat analysis. Percent fat increased with age: 16-19
years (n = 29, 26%), 20-29 years (n = 100, 29%), 30-39 years (n = 58, 33%), 40-49 years (n = 48, 35%), and 50-68 years (n = 37, 39%). Although these results seem to repeat what many other researchers have reported it should be noted that the subject sample was not random. The purpose of the study was not to assess the relationship between lean body mass and age, but rather to judge the predictability of skinfolds, and therefore an attempt was made to select a variety of body types.

Pollock et al. (1975) were also interested in the accuracy of anthropometric prediction equations for body density and thus studied 83 healthy college female students (18-22 years) and 60 middle age women (33-50 years). They also performed comparative hydrostatic weighing measurements. The residual volumes were determined prior to the weighing in a seated position via a closed circuit helium technique. The equation of Siri (1956) was used for percent fat determination, and the women were evaluated at least seven days prior to or after their period.

The average mass of the young women (mean age 20.2) was 57.53 kg and the average percent fat was 24.8. In the older women (mean age 44.7) these figures were 61.22 kg and 29.8% with very similar standard deviations to those of the younger women.

A study concerned with the influence of activity, obesity, and age on the fat-free mass of adults (Womersley et al., 1976) compared sedentary, muscular, and obese young
and older women. They were weighed hydrostatically; residual volume was determined by three breath nitrogen dilution; and percent fat was calculated utilizing Siri's equation (1956). The groups of subjects were not randomly chosen nor grouped by decade for statistical treatment. The group which represented sedentary young women (n = 12) reflected body composition values similar to those reported in the literature. The average age was 21.9 (range 16-32), the average mass was 55.9 kg, and the average percent fat was 25 (range 13%-36%).

In 1977, Slaughter, Lohman, and Boileau researched the lean body mass of 53 healthy college women ages 17-22 (average 19.82 years) by hydrostatic weighing using an electric scale. Residual volume was measured while the subject was submerged using a modification of a closed circuit nitrogen washout (oxygen dilution) method. Body density was converted to percent fat using the formula of Brozek (1963). The average weight for this group was 57.4 kg and the body fat was 24.8%, ranging from 17.6%-34.5%.

The following two studies both reported on the effects of exercise on body composition. In each case a pre-exercise program hydrostatic weighing test was performed on all subjects.

Noland, Melody, and Kearney (1978) tested 56 college women (average age 19) and reported average weights of 60.31 kg in one group (n = 27) and 59.48 kg in the other (n = 29). They were divided into two equal groups, each
to undergo a different exercise program. Average percent fat using Brozek's (1963) formula was 20.58, and 22.0% for the respective groups.

Krahenbuhl, Archer, and Pettit (1978) studied only 13 females because of the nature of required serum testosterone tests. Residual volume was estimated at .28 of the vital capacity, Brozek's (1963) percent fat equation was used, and the women were weighed on the eighth day of the menstrual cycle. The mean age of the group was 21.3 years, the mean weight was 60.9 kg, and mean percent fat 25.2.

Another significant study analyzed anthropometric prediction equations (Jackson, Pollock, & Ward, 1980) with female subjects, and the findings tended to reinforce previous research. Two hundred forty nine women were hydrostatically weighed, residual volume was measured by either nitrogen washout or helium dilution, and body fat was calculated by Siri's formula (1956). The results were recorded by decade age groupings and the results reported as follows: 17-19 years (n = 25, 24.8% fat); 20-29 years (n = 102, 21.8% fat); 30-39 years (n = 57, 22.7% fat); 40-49 years (n = 48, 27.3% fat); and 50-59 years (n = 17, 32.1% fat). As demonstrated in previous research, significant change in female percent body fat appears to occur in the fifth decade or after age 40.

An additional study which used hydrostatic weighing as the sole means of determining body composition (Jackson, 1979) was reported in abstract format. Two hundred eighty
three women, ages 18-55 (average 24.4 years) averaged 30.9% fat with a standard deviation of 11.0%.

Two other studies utilized potassium 40 counting rather than hydrostatic weighing. Forbes and Reina (1970) compared the data collected on 9000 men and 3000 women from six different studies utilizing potassium 40 counting and reported the following generalized observations with reference to age:

a) Estimated lean body mass is highest in the third decade (20-29 years) after which it falls slowly for the next two decades and then more rapidly.

b) Body fat content progressively rises.

c) The decrease in lean body mass occurs more slowly in women than in men, the significant decline beginning in the fifth or sixth decade.

d) In the 42 years following age 25, male lean body mass declined by approximately 12 kg, and the female by only 5 kg.

e) Linear regressions calculated for five of the six groups of data on males showed an average of .123 kg of lean body mass loss per year (or approximately one-fourth pound) in the third, fourth, and fifth decades.

Novak (1972) used K₄₀ for observations of 215 men and 305 women. The findings with reference to age and sex followed the same trends with women beginning with less lean body mass at a slower rate than men.
In summary, these studies have presented body composition information on women ranging in age from 16 to 69 years, with the majority of the information pertaining to those in their early 20's. The measurements in most of these studies were densitometric, but measurement technique and formulae for calculation of body density and residual volume varied. This review thus indicates a need for more data particular to older non-athletic women, as well as a need for consistency of measuring methods and calculations so that data for each population is more comparable.
CHAPTER III

Research Methods and Design

Subjects

Fifty-three women between the ages of 22 and 62 volunteered to participate in this study. In an effort to obtain the best random population, women were solicited from several different sources, including students, staff, and faculty of the California State University, Northridge campus, and citizens of the surrounding community. A prerequisite for participation in this study was that subjects must not have been trained athletes in the previous ten years.

The subjects for this research study were categorized into groups by age decade: 30-39, 40-49, and 50-59 for the development of normative standards. Limited data on women in their twenties and sixties was used for comparison of other body composition values reported in the research literature.

Subject Orientation

Initial contact with each subject was conducted by telephone conversation. At this time the subject was given a brief description of the study, and standardized instructions pertaining to the pretest physical state most conducive to valid hydrostatic weighing (Girandola, Wiswell,
& Romero, 1977). These instructions included no food intake or exercise for at least eight hours prior to test administration (Appendix A).

The first appointment was arranged for approximately the seventh day of the menstrual cycle, or longer if the flow exceeded nine days. In the case of an irregular menstrual cycle the subject notified the investigator at the onset of menses and at this time the first testing date was determined.

Immediately prior to being tested the subject was requested to fill out two questionnaires. The first questionnaire was used to determine age, physical activity levels, and the regularity of the menstrual cycle (Appendix A). This questionnaire also contained a consent form for the subject to read and sign (Appendix A). The second questionnaire was utilized to determine whether or not the subject had followed the instructions as to the desired pretest physical state (Appendix A).

**Anthropometric Body Composition Evaluation**

The anthropometric body composition analyses were performed on all subjects. Thirteen skinfold sites were selected for measuring using Lange Skinfold Spring-loaded Calipers (Cambridge Scientific, Inc., Cambridge, Maryland). Each site was selected from one or more of the following protocols: Allen's ten skinfold sides (Allen, Peng, Chen, Huang, Chang, & Fang, 1956); Yuhasz's six skinfold sites (Yuhasz, 1974); or Durnin's four skinfold sites (Durnin &
Rahaman, 1967). Each skinfold was measured on the left as well as the right side of the body. On the right side of the body both horizontal and vertical measurements were obtained. The measurements were made at precisely measured anatomical points by the use of horizontal and vertical skin marks. Skinfolds were grasped firmly between the thumb and forefinger while the calipers were placed approximately one centimeter above. Measurements were read immediately before the subcutaneous fat could be compressed at measurement sites. Each site was measured three times and an average used for calculations. Circumferences were also measured according to the procedures of McArdle et al. (1977). Landmarks used for each skinfold site were:

a) Cheek - taken vertically at the point of intersection of an imaginary line drawn vertical from the lateral edge of the eye and a line horizontal from the corner of the mouth.

b) Chin - taken vertically directly above the Adam's apple.

c) Biceps - taken vertically on the anterior midline of the upper arm, over the midpoint of the muscle belly, with the elbow extended and relaxed.

d) Triceps - taken vertically on the posterior midline of the upper arm midway between the olecranon and the tip of the acromion, with the elbow extended and relaxed.
e) Chest - a diagonal fold one-third of the distance between the corner of the axillary fold and the nipple of the breast.

f) Suprailiac - diagonal fold directly above the crest of the ilium.

g) Abdominal - taken vertically adjacent to and one inch lateral to the umbilicus.

h) Side - a diagonal fold taken at the fifth rib directly below the nipple of the breast.

i) Subscapular - taken on a diagonal line one inch from the inferior angle of the scapula.

j) Anterior thigh - the subject should have her weight on her left foot and have the right foot slightly forward and the right knee slightly bent and relaxed. The skinfold is raised midway on the anterior of the thigh between the hip joint and the patella. The fold is lifted parallel to the long axis of the body. This position is reversed for measurement of the left extremity.

k) Anterior knee - the subject should be in the same position as above. A vertical fold is taken directly above the kneecap.

l) Posterior thigh - the subject should be in the same position as above. The skinfold is raised parallel to the long axis of the leg, medway on the posterior of the thigh between the hip and knee joints. In order to obtain a vertical fold at this site it was often necessary to have the subject raise the lower leg parallel to the floor, thus
easing the tension of the thigh skin.

m) Posterior knee - the subject should be in the same position as above. A vertical fold is taken directly below the fold of the knee on the midline of the leg. Again, it was sometimes necessary for the subject to raise the lower leg parallel to the floor.

Landmarks for each circumference site were:

a) Abdominal circumference - one inch above the umbilicus.
b) Right thigh circumference - upper thigh just below the buttocks.
c) Right forearm circumference - maximum circumference with the arm extended in front of the body with palm up.
d) Right calf circumference - widest circumference midway between the ankle and knee.

Height and weight were measured to the nearest one-half inch and one-fourth pound, utilizing a Detecto Spring Scale.

**Anthropometric Test Formulae**

The formulae for the analyses of these anthropometric tests included:

a) Allen's (Allen et al., 1956) ten skinfolds - cheek, chin, triceps, chest, suprailiac, abdominal, side, subscapular, anterior knee, and posterior knee.

\[
A = \text{TBM} \cdot \frac{\left( \tau \times \text{S.A.} \times 0.739 \right)}{\text{TBM}} - 0.003
\]
where: \( A = \text{adiposity} \)

\[
\text{TBM} = \text{total body mass (kg)}
\]

\[
\tau = \frac{10 \text{ skinfolds} - 40 \text{ mm}}{20}
\]

S.A. = surface area (Dubois Body Surface Chart as prepared by Boothby and Sandiford of the Mayo Clinic)

b) Yuhasz's six skinfolds (Yuhasz, 1974) - triceps, suprailiac, abdominal, subscapular, anterior thigh, posterior thigh.

Young women (19-26) \( 6 \text{ skinfolds} \times 0.217 - 4.47 = \% \text{ fat} \)

Older women (26-50) \( 6 \text{ skinfolds} \times 0.224 - 2.80 = \% \text{ fat} \)

c) Durnin's four skinfolds (Durnin et al., 1967) - biceps, triceps, suprailiac, subscapular. Refer to Durnin and Womersly (1974, p. 95) for percent body fat as calculated by age and sum of four skinfolds.

d) McArdle's three circumferences (McArdle et al., 1977) - (1) abdomen, (3) right thigh, (3) right forearm, (4) right calf.

Women ages 17-26 years \( \% \text{ fat} = (1) + (2) - (3) - 19.6 \)

Women ages 27-50 years \( \% \text{ fat} = (1) + (2) - (4) - 18.4 \)

Refer to McArdle et al. (1981, pp. 385-386) for conversion constants for younger women (1, 2, 3) and McArdle et al. (1981, pp. 387-388) for conversion constants for older women (1, 2, 4).
Densitometric Body Composition Evaluation

Densitometric body composition analysis was performed on all subjects. Each subject was tested at approximately the seventh, eight, or ninth day of the menstrual cycle, or later if the flow exceeded nine days. The reason for this being it is well documented that cyclic weight changes caused by hormonal variation occur during the different phases of the menstrual cycle (Robinson & Watson, 1969). Post menopausal women were measured at their convenience.

In preparation for measurement of vital capacity subjects were initially directed to do some stretching and deep breathing exercises for the thoracic cavity. While performing these stretches the purpose and procedure for hydrostatic weighing was briefly described by the investigator, with the intention that a better understanding would elicit a closer to maximum performance. To measure vital capacity, clips were placed on the subjects' nose to eliminate air flow. After a maximum inhalation, a maximal exhalation was performed into a Collin's six liter water spirometer. During the final phase of exhalation subjects flexed forward at the waist in an attempt to expel all possible air, and to be in similar position to that underwater. Three trials were recorded and an average calculated. To estimate residual lung volume the average vital capacity was converted to vital capacity BTPS (Body Temperature Pressure Saturated) using conversion factors for the
spirometer water temperature, and then multiplied by .28 (Wilmore, 1969).

Body density was determined by the ratio of weight under water to mass in air. The tank utilized for this procedure was designed by Dr. George Q. Rich III (California State University, Northridge). Tank measurements were 30" by 48" by 42" deep and contained approximately 225 gallons when filled to working depth. A Chatillon autopsy scale was suspended from a steel frame, and from this a subject seat measuring 18" by 24" was hung in the water (Rich & Scherer, 1980).

Subjects were instructed how to enter the tank, straddle the seat, and sit near the rear of the seat with legs crossed in front, with hands grasping the seat adjacent to hips. The following set of instructions were given:

a) Wet hair and squeeze air bubbles from hair and swim suit.

b) Hyperventilate using approximately 4 to 5 deep breaths.

c) Open mouth and forcefully expel all air.

d) Gradually flex at the waist, submerging head and upper body beneath the water.

e) Continue to expel any remaining air.

f) Sit motionless and relax.

g) Wait for investigator's signal to surface unless the need to come up sooner prevails.
While each trial was being recorded the investigator reminded the subject of the correct procedure. The investigator rested her forearms on the edge of the tank for a controlled grip on the seat's suspension ropes, to stabilize the subject while above water, and for damping when reading the scale. Five measurements were taken, however if a subject came up before the scale was adequately stillled and a stable scale reading obtained, an additional trial was conducted.

**Densitometric Test Formulae**

The final four densitometric measurements were averaged and tare weight and tank water temperature were recorded. Calculation of body density and body fat were based upon the equations of Brozek et al. (1963). The formulae are as follows:

\[
Db = \frac{Ma - Mw}{Dw} - (RV - VGI)
\]

\[
\text{Fat} \% = \frac{4.570}{Db} - 4.142 \times 100
\]

where:

- \(Db\) = Density of body
- \(Ma\) = Mass in air (kg)
- \(Mw\) = Mass in water (kg)
- \(Dw\) = Density of water
- \(RV\) = Residual Lung Volume
- \(VGI\) = Volume of gas in intestinal tract (.115)

**Replication**

All of the entire mentioned tests were rerun on nine of the subjects to determine reliability. An attempt was made to repeat as closely as possible the circumstances of
first tests; same time of day, pretest state, and day of the menstrual cycle.

Menarche

To study the possible differences that variable points of the menstrual cycle might have on hydrostatic weight, the original tests were repeated on ten women under the same circumstances with the exception that this measurement was taken on the twentieth, twenty-first, or twenty-second day into the cycle (Young, Martin, Chihan, McCarthy, Manniello, Harmuth, & Fryer, 1961). For six of these women the twenty-first day measurement was the first test, and the seventh day was second so that learning would not influence the results.

Statistical Treatment of Data

Pearson's correlation, stepwise multiple regression, and t-tests were used for the statistical analysis. These programs were selected from the Statistical Package for Social Sciences (SPSS) computer programs at California State University, Northridge. An analysis of variance program (BMDP2V), available from the Health Sciences Computer Facility of California State University, Los Angeles was also used in the California State University, Northridge computer.

1. Descriptive data was calculated for each of the following variables: age, weight, percent body fat by hydrostatic weighing, Allen's ten skinfolds, Yuhasz's six
skinfolds, Durnin's four skinfolds, and McArdle's four circumferences.

2. A Pearson correlation aided in determining the extent to which the five body composition assessment methods were interrelated.

3. An analysis of variance (BMDP2V) program aided in determining whether the differences between the five body composition assessment measurements were significant. A Tukey's post hoc test was used with this to determine locations of significant group differences.

4. A stepwise multiple regression was used to determine which skinfold sites best predicted percent body fat as measured densitometrically. The skinfold sites included: cheek, chin, biceps, triceps, chest, suprailiac, abdominal, side, subscapular, anterior thigh, posterior thigh, anterior knee, and posterior knee.

5. T-tests were used to determine the reliability of percent fat estimations of nine subjects. First and second trials of percent body fat by hydrostatic weighing, Allen's, Yuhasz's, and Durnin's right vertical skinfolds, and McArdle's circumferences were compared. T-tests were also used to compare measurements on approximately the seventh and twenty-first day of the menstrual cycle for ten women. Variables included weight in pounds, densitometric percent fat estimations, and Durnin's right vertical skinfold measurements.
CHAPTER IV

Statistical Analysis of the Data

Descriptive Data

The purpose of this study was to collect and collate data regarding the percent body fat norms of women in the age group decades 30-39, 40-49, and 50-59. For analyzing the data specific to this purpose a frequencies program design was utilized. This design provided descriptive data for: age; weight; percent body fat by hydrostatic weighing; Allen's ten right and left vertical, and right horizontal skinfolds; Yuhasz's six right and left vertical, and right horizontal skinfolds; Durnin's four right and left vertical, and right horizontal skinfolds; as well as McArdle's three circumferences for younger and older women. The measurements of these variables particular to each subject are listed in Appendix B. Means and standard deviations for these variables are illustrated in Table 1.

In comparing means it was found: women between the ages of 30-39 (average = 34.59 years) weighed an average of 126.92 pounds and were 28% fat as measured densitometrically; women between the ages of 40-49 (average = 43.39 years) weighed 128.05 pounds and were 30.75% fat; and women ages 50-59 (average = 53.09 years) weighed 134.57 pounds and were 36.24% fat. The increase in age from the 30's to the 40's represented an average increase in weight of only
## Table 1

### Means and Standard Deviations of Percent Fat Estimations

<table>
<thead>
<tr>
<th></th>
<th>30-59 Mean</th>
<th>30-39 Mean</th>
<th>40-49 Mean</th>
<th>50-59 Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 45</td>
<td>n = 15</td>
<td>n = 15</td>
<td>n = 15</td>
</tr>
<tr>
<td><strong>Age in Years</strong></td>
<td>43.7 8.06</td>
<td>34.59 3.24</td>
<td>43.39 2.23</td>
<td>53.09 2.33</td>
</tr>
<tr>
<td><strong>Weight in Pounds</strong></td>
<td>129.84 17.95</td>
<td>126.92 14.77</td>
<td>128.05 16.79</td>
<td>134.57 21.82</td>
</tr>
<tr>
<td><strong>Hydrostatic % Fat</strong></td>
<td>31.70 6.36</td>
<td>28.10 6.97</td>
<td>30.75 4.51</td>
<td>36.24 4.59</td>
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<tr>
<td><strong>Allen's S.F. % Fat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Vertical</td>
<td>29.32 6.97</td>
<td>29.14 7.37</td>
<td>27.64 6.09</td>
<td>31.13 7.38</td>
</tr>
<tr>
<td>Left Vertical</td>
<td>29.49 6.92</td>
<td>29.21 7.44</td>
<td>28.34 5.95</td>
<td>30.91 7.49</td>
</tr>
<tr>
<td>Right Horizontal</td>
<td>29.34 6.33</td>
<td>29.08 6.29</td>
<td>27.95 5.95</td>
<td>31.01 6.77</td>
</tr>
<tr>
<td><strong>Yuhasz's S.F. % Fat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Vertical</td>
<td>28.14 9.37</td>
<td>29.71 11.29</td>
<td>25.11 7.07</td>
<td>30.61 9.05</td>
</tr>
<tr>
<td>Left Vertical</td>
<td>28.24 9.26</td>
<td>28.47 11.26</td>
<td>25.72 7.00</td>
<td>30.52 9.01</td>
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<tr>
<td>Right Horizontal</td>
<td>26.91 8.74</td>
<td>27.32 10.17</td>
<td>24.15 6.82</td>
<td>29.28 8.72</td>
</tr>
<tr>
<td><strong>Durnin's S.F. % Fat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Vertical</td>
<td>31.20 5.53</td>
<td>29.15 5.54</td>
<td>30.04 3.93</td>
<td>34.41 5.75</td>
</tr>
<tr>
<td>Left Vertical</td>
<td>31.21 5.50</td>
<td>29.18 5.51</td>
<td>29.80 3.90</td>
<td>34.66 5.49</td>
</tr>
<tr>
<td>Right Horizontal</td>
<td>31.97 5.29</td>
<td>29.90 4.99</td>
<td>30.60 4.23</td>
<td>35.40 5.11</td>
</tr>
<tr>
<td><strong>McArdle Circumferences % Fat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young Women</td>
<td>22.65 7.30</td>
<td>22.58 7.74</td>
<td>20.53 7.27</td>
<td>24.84 6.70</td>
</tr>
<tr>
<td>Older Women</td>
<td>22.29 4.18</td>
<td>22.51 3.87</td>
<td>20.93 3.74</td>
<td>23.44 4.75</td>
</tr>
</tbody>
</table>
1.13 pounds, while the percent fat increased 2.75%. The increase in age from the 40's to the 50's revealed an average increase in weight of 6.52 pounds and a 5.49% increase in body fat. These findings concur with the mean values found for women in studies by Chen (1953) and Durnin and Womersley (1974). Although the percent fat values vary from those of other studies, the magnitude of the increase from one decade to the next was similar to that reported by Young, Blondin, Tensuan, and Fryer (1963), Jackson, Pollock, and Ward (1980), and Forbes and Reina (1970). All of these studies reported the most significant increase in percent body fat to occur after the fifth decade.

With the exception of McArdle's circumferences, means of the anthropometrically determined percent body fat value appear to be reasonably similar to those determined densitometrically. Standard deviations are slightly higher for the anthropometrically determined percent fat values than densitometric values.

Relationship Between Body Compositional Protocols

In order to determine the extent to which five body composition assessment methods were interrelated, a Pearson Correlation was applied. Resulting values appear in Table 2.

Correlation coefficients in Table 2 demonstrate support for the population specificity concept of body composition determination by anthropometry. Coefficients for women in the age group 30-39 ranged from .72 to .87. The
Table 2

Correlation Coefficients and Mean Differences Between Hydrostatic Percent Fat vs. Anthropometrically Determined Percent Fat

<table>
<thead>
<tr>
<th></th>
<th>30-59</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
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<tbody>
<tr>
<td></td>
<td>( r )</td>
<td>( X_H - X_A ) LOC</td>
<td>( r )</td>
<td>( X_H - X_A ) LOC</td>
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<tr>
<td>Allen's S.F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Vertical</td>
<td>.6091</td>
<td>2.38</td>
<td>.05</td>
<td>.8352</td>
</tr>
<tr>
<td>Left Vertical</td>
<td>.5667</td>
<td>2.21</td>
<td>no</td>
<td>.8171</td>
</tr>
<tr>
<td>Right Horizontal</td>
<td>.5816</td>
<td>2.36</td>
<td>.05</td>
<td>.7995</td>
</tr>
<tr>
<td>Yuhasz's S.F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Vertical</td>
<td>.6247</td>
<td>3.56</td>
<td>.01</td>
<td>.7979</td>
</tr>
<tr>
<td>Left Vertical</td>
<td>.6190</td>
<td>3.46</td>
<td>.01</td>
<td>.7785</td>
</tr>
<tr>
<td>Right Horizontal</td>
<td>.6150</td>
<td>4.79</td>
<td>.01</td>
<td>.7932</td>
</tr>
<tr>
<td>Durnin's S.F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Vertical</td>
<td>.7125</td>
<td>.5</td>
<td>no</td>
<td>.7527</td>
</tr>
<tr>
<td>Left Vertical</td>
<td>.6975</td>
<td>.49</td>
<td>no</td>
<td>.7268</td>
</tr>
<tr>
<td>Right Horizontal</td>
<td>.6773</td>
<td>-.27</td>
<td>no</td>
<td>.7266</td>
</tr>
<tr>
<td>McArdle Circumferences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young Women</td>
<td>.4737</td>
<td>9.05</td>
<td>.01</td>
<td>.4217</td>
</tr>
<tr>
<td>Older Women</td>
<td>.5727</td>
<td>9.41</td>
<td>.01</td>
<td>.8743</td>
</tr>
</tbody>
</table>

\( r \) = Pearson's correlation coefficient

\( X_H - X_A \) = The level of confidence of the mean difference as determined by Tukey's Honestly Significant Difference

LOC = Level of Confidence
correlation coefficients for women in age groups 40-49, 50-59, and 30-59 were not as high, ranging from .39 to .71. The McArdle circumferential estimations of percent body fat correlated with hydrostatically determined fat .47 to .57 for all ages (30-59).

Significance of Differences Between Body Composition Protocols

For insight into the validity of anthropometric body composition assessment, an analysis of variance program was used along with Tukey's post hoc test. The purpose was to determine whether differences between the various anthropometric and hydrostatic weighing values were significant within each decade group. These values also appear in Table 2.

In the age group 30-39 there were no significant mean differences among various body composition protocols, with the exception of McArdle's circumferences which were significantly different (.01). In the age group 40-49 there were only two protocols, Allen's and Durnin's which were not significantly different from densitometric values. In the last two age groups, 50-59 and 30-59, the protocols all differed significantly from hydrostatic values with the exception of Durnin's percent fat values.

These results indicated that anthropometric determinations of percent body fat as dictated by the protocols of Allen, Yuhasz, Durnin, and McArdle are reasonable alternatives to hydrostatic weighing for women in the 30's, but
not always for women in the 40's and 50's. It is possible that these formulae were derived utilizing data of younger women, and are thus not applicable to older age groups. Durnin's values were the only ones which predicted hydrostatic percent body fat consistently throughout the various age groups.

**Significance of Differences Between Skinfold Techniques**

Correlation coefficients and mean difference values lend insight into the use of right vertical versus left vertical skinfold measurements, and of right vertical versus right horizontal skinfold measurements. Referring to Table 2 the mean differences between these variables, within each protocol, were very small. In every case, with the exception of Allen's protocol for the age group 30-59, significance levels of mean difference values for right vertical skinfolds were the same as left vertical skinfold values. This was also true in comparing right vertical to right horizontal values. The differences were all among protocols, rather than within them. Lack of significant differences between these procedures indicates there is no reason to change to a new method from the right vertical fold, which traditionally has been the universal approach to skinfold measurement.

**Predictive Value of Skinfold Sites**

The previous tests were concerned with the accuracy of four commonly used body composition assessment protocols.
It has been suggested that separate body composition equations are necessary for different populations to differentiate age group and sex differences (Durnin & Rahaman, 1967; Pollock et al., 1975). Thus, to detect any differences among age decades, the thirteen skinfold sites which were used in one or more of the skinfold protocols (Allen et al., 1956; Yuhasz, 1974; Durnin et al., 1967) were considered separately and in new combinations. Skinfold sites included: cheek, chin, biceps, triceps, chest, suprailiac, abdominal, side, subscapular, anterior thigh, posterior thigh, anterior knee, and posterior knee. Research intent was to determine which skinfold sites, alone or in combination, best predicted body fat as measured densitometrically for age groups 22-62, 30-39, 40-49, and 50-59.

A stepwise multiple regression computer program was utilized for this purpose. The data for age, hydrostatically determined percent fat, and right vertical skinfold thicknesses at each of the thirteen sites was applied.

Table 3 illustrates the order in which the sites are most predictive for each group, and at what point the addition of one more site has a negligible difference on the outcome of the estimation. Included also in this table are the multiple R values. These values appraise the correlation of hydrostatically measured percent fat with the skinfold prediction when each anatomical site is factored in. A line is then drawn where the correlation no
### Table 3

Stepwise Multiple R Values Between Skinfold Sites and Densitometric Percent Fat

<table>
<thead>
<tr>
<th></th>
<th>22 - 62</th>
<th>30 - 39</th>
<th>40 - 49</th>
<th>50 - 59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side</td>
<td>.6780</td>
<td>Abdomen</td>
<td>.7913</td>
<td>Post. Thigh</td>
</tr>
<tr>
<td>Ant. Thigh</td>
<td>.7534</td>
<td>Side</td>
<td>.8594</td>
<td>Biceps</td>
</tr>
<tr>
<td>Chest</td>
<td>.7620</td>
<td>Ant. Thigh</td>
<td>.8753</td>
<td>Ant. Knee</td>
</tr>
<tr>
<td>Suprailiac</td>
<td>.7649</td>
<td>Subscapular</td>
<td>.8877</td>
<td>Abdomen</td>
</tr>
<tr>
<td>Ant. Knee</td>
<td>.7669</td>
<td>Suprailiac</td>
<td>.9240</td>
<td>Subscapular</td>
</tr>
<tr>
<td>Post. Knee</td>
<td>.7722</td>
<td>Chest</td>
<td>.9626</td>
<td>Chin</td>
</tr>
<tr>
<td>Subscapular</td>
<td>.7737</td>
<td>Triceps</td>
<td>.9680</td>
<td>Side</td>
</tr>
<tr>
<td>Triceps</td>
<td>.7750</td>
<td>Post. Knee</td>
<td>.9790</td>
<td>Triceps</td>
</tr>
<tr>
<td>Cheek</td>
<td>.7759</td>
<td>Post. Thigh</td>
<td>.9868</td>
<td>Ant. Thigh</td>
</tr>
<tr>
<td>Chin</td>
<td>.7765</td>
<td>Ant. Knee</td>
<td>.9885</td>
<td>Cheek</td>
</tr>
<tr>
<td>Biceps</td>
<td>.7768</td>
<td>Chin</td>
<td>.9924</td>
<td>Chest</td>
</tr>
<tr>
<td>Abdomen</td>
<td>.7771</td>
<td>Biceps</td>
<td>Suprailiac</td>
<td>.9956</td>
</tr>
</tbody>
</table>
longer improves appreciably with the addition of one or more skinfolds.

In observing these data it is evident that for each age group a different combination of skinfolds provides for the best prediction of percent fat. These combinations are as follows: 22 to 62 years, side, anterior thigh, and chest; 30-39 years, abdomen, side, anterior thigh, subscapular, suprailiac, and chest; 40-49 years, posterior thigh, biceps, anterior knee, abdomen, subscapular, chin, side, triceps, anterior thigh, and cheek; and 50-59 years, side, posterior thigh, cheek, abdomen, chin, suprailiac, subscapular, anterior thigh, biceps, triceps, and chest.

It also appears that although the correlations between skinfolds and hydrostatic percent fat are high for all groups, the correlations are superior when the equations are specific to decade age groups (30's, 40's, and 50's), as opposed to the entire group (22-62). Correlations ranged from .678 to .777 for the whole group, and from .791 to .999, .842 to .996, and .633 to .999 for the 30's, 40's, and 50's respectively. Although correlations started just above .60 in the 50 year group as it did for the whole age range, the potential correlation with the addition of all sites was much greater within the individual decades (.9 as opposed to .7). These findings suggest that adipose proportions are specifically modified with age, and thus the prediction formulae should be selective to age groups.
New Skinfold Percent Fat Prediction Formulae

A multiple regression program outlined a best predictor formula to be used with skinfold measurements for each group. These formulae are listed in Table 4.

To test the value of these new formulae, right vertical skinfold data for each site, as designated by the appropriate formula, was applied. This was conducted for each subject using both the whole group formula, and the formula specific to each subject's age group. The resulting two new percent fat predictions were then compared to the individual's hydrostatic percent fat. Resultant data are displayed in Table 5.

To determine the significance of any differences observed between these percent fat figures, paired t-tests were used. Results of these are listed in Table 6. Once again, the correlation between hydrostatic percent fat and each of the other percent fat values is high, but the correlation is much higher for values specific to individual decades (.966, .986, and .994) than for the whole group (.743). None of the paired t values are significant at the .05 level of confidence. These findings are further evidence supporting the theory that body composition evaluation formulae are population specific.

Comparison of Two Menstrual Cycle Testing Dates

An additional aspect of this study was to analyze the fluctuating body composition of ten women on approximately
Table 4  
Formulae for Percent Fat Prediction by Skinfold

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Regression Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 - 62</td>
<td>Percent fat = .334 (side) + .248 (anterior thigh) + .198 (chest) + 16.947 ± 4.55</td>
</tr>
<tr>
<td>30 - 39</td>
<td>Percent fat = .419 (abdomen) + 1.067 (side) + .080 anterior thigh) - .973 (subscapular) + .666 (suprailiac) - .701 (chest) 16.006 ± 2.656</td>
</tr>
<tr>
<td>40 - 49</td>
<td>Percent fat = .528 (posterior knee) - .184 (bicep) + .184 (anterior knee) + 0.41 (abdomen) - .127 (subscapular) - .707 (chin) + .382 (side) + .963 (tricep) - .691 (anterior thigh) + .865 (cheek) + 10.681 ± 1.044</td>
</tr>
<tr>
<td>50 - 59</td>
<td>Percent fat = 1.823 (side) + .141 (posterior thigh) + 2.802 (cheek) - .500 (abdomen) + .082 (chin) - 1.151 (suprailiac) - .210 (subscapular) - .490 (anterior thigh) + 1.499 (bicep) - 1.212 (tricep) + .533 (chest) + 26.533 ± 1.11</td>
</tr>
</tbody>
</table>
Table 5
Percent Fat Estimations, Hydrostatic vs. Predicted

<table>
<thead>
<tr>
<th>Age</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Age</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tbody>
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<td>21</td>
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<td>30</td>
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<td>30</td>
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A = Percent fat hydrostatic  
B = Percent fat by regression formula for 22-62 years  
C = Percent fat by regression formula for decade groups
Table 6

Paired T-tests of Hydrostatic Percent Fat vs. Percent Fat
as Estimated by Regression Equations

<table>
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<td>6.82</td>
<td>.743</td>
<td>.19</td>
<td>no</td>
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<tr>
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<td>31.87</td>
<td>5.43</td>
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<td></td>
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<tr>
<td>% Fat Hydrostatic</td>
<td>28.19</td>
<td>7.20</td>
<td>.966</td>
<td>-.42</td>
<td>no</td>
</tr>
<tr>
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<td>28.39</td>
<td>7.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Fat Hydrostatic</td>
<td>30.75</td>
<td>4.50</td>
<td>.986</td>
<td>-.87</td>
<td>no</td>
</tr>
<tr>
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<td>30.92</td>
<td>4.35</td>
<td></td>
<td></td>
<td></td>
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<td>% Fat Hydrostatic</td>
<td>36.21</td>
<td>4.58</td>
<td>.994</td>
<td>-.10</td>
<td>no</td>
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<td>% Fat Predicted</td>
<td>36.23</td>
<td>4.55</td>
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the twenty-first versus the seventh day of the menstrual cycle. Current literature indicates that fluctuating hormone levels associated with the menstrual cycle may affect the state of hydration and, therefore, body density (Robinson & Watson, 1968). The twenty-first day test mirrored as closely as possible the seventh day test, including time of day, pre-test state, and variables measured.

In analyzing the data, t-tests were used to compare the seventh and twenty-first day measurements. Variables applied included weight in pounds, densitometric percent far estimations, and percent fat as predicted by Durnin's right vertical skinfold measurements. Subject data are found in Appendix B and the t-test results are illustrated in Table 7.

Table 7
T-tests of Influence of Menstrual Cycle on Body Composition Tests (N = 10)

<table>
<thead>
<tr>
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<th>Weight</th>
<th>% Fat</th>
<th>Hydro</th>
<th>% Fat Durnin</th>
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<tr>
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<td>Day 21</td>
<td>Day 7</td>
<td>Day 21</td>
<td>Day 7</td>
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<tr>
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<td>132.60</td>
<td>133.28</td>
<td>29.65</td>
<td>29.43</td>
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<tr>
<td>S.D.</td>
<td>26.72</td>
<td>26.28</td>
<td>10.34</td>
<td>10.00</td>
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<td>Corr.</td>
<td>.9980</td>
<td>.9905</td>
<td>.9894</td>
<td></td>
</tr>
<tr>
<td>Paired T</td>
<td>1.2408</td>
<td>-.4780</td>
<td>1.570</td>
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In reviewing these results a comparison of seventh versus twenty-first day weight in pounds, hydrostatic percent fat, and percent fat by Durnin's right vertical
skinfolds elicited paired-t values of 1.241, -.478, and 1.57, none of which were significant. Correlation coefficients for these variables respectively were .9980, .9905, and .9894. These high correlations and insignificant t-values indicate a negligible difference between the two menstrual cycle testing dates. It appears that there are at least two weeks of the adult menstrual cycle during which consistent body composition analyses can be conducted without adverse influence by fluctuating hormone levels.

Reliability of Test Data

The final question to be answered statistically was whether or not the percent fat estimates were reliable. Ten women were selected for replicative measurement of all variables. The time of day, pre-test state, and day of the menstrual cycle were repeated as closely as possible.

T-tests were used to compare first and second trials of percent body fat by hydrostatic weighing, Allen's, Yuhasz's, and Durnin's right vertical skinfolds, McArdle's circumferences, and weight in pounds. These data are presented in Appendix B. The results, appearing in Table 8, indicated high correlations ranging in value from .964 to .991 for each variable. The paired t values were all insignificant, except Allen's skinfolds, ranging from .062 to 1.861. These data signify reliable test data for the chosen laboratory protocols.
Table 8

T-tests for Replication Analyses, Trial 1 vs. Trial 2
of Body Composition Measurements (N = 9)

<table>
<thead>
<tr>
<th>% Fat Hydro</th>
<th>% Fat Allen</th>
<th>% Fat Yuhasz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>30.42</td>
<td>30.43</td>
</tr>
<tr>
<td>S.D.</td>
<td>6.21</td>
<td>6.40</td>
</tr>
<tr>
<td>Corr.</td>
<td>.991</td>
<td></td>
</tr>
<tr>
<td>Paired T</td>
<td>-.062</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>% Fat Durnin</th>
<th>% Fat McArdle</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #</td>
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<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>30.32</td>
<td>29.79</td>
</tr>
<tr>
<td>S.D.</td>
<td>6.10</td>
<td>4.95</td>
</tr>
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<td>Corr.</td>
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<td>Paired T</td>
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CHAPTER V

Summary and Conclusions

Summary of Procedures

Body composition of 53 women was analyzed using both hydrostatic and anthropometric measurements. Variables included: age; weight; hydrostatic percent body fat; right vertical, left vertical, and right horizontal measurements of Allen's, Yuhasz's, and Durnin's skinfolds; as well as McArdle's circumferences. These measurements were used for: 1) determination of percent body fat norms for each of three age group decades, 2) comparison of three skinfold techniques, and 3) comparison of percent fat values obtained at two different stages of the menstrual cycle.

Summary of Major Findings

1. Average percent body fat as measured densitometrically increased 2.65% from the fourth to the fifth age decade, and 5.49% from the fifth to the sixth decade.

2. Progression in age from the thirties to the forties, and from the forties to the fifties had corresponding increases in body weight of 1.13 pounds and 6.52 pounds.

3. The mean body fat percentages as estimated by anthropometric measurements were not significantly
different from the hydrostatic percent fat, with the exception of McArdle's circumferences.

4. For the age group 30-39, mean body fat percentages as estimated by skinfold measurements were not significantly different from the mean hydrostatic values. For all other age groups the only skinfold protocol which predicted percent fat with no significant difference from hydrostatic percent fat was that of Durnin.

5. Less deviation from the mean was present in the hydrostatic measurement of percent fat than in the anthropometric measurements.

6. The correlation coefficients relating each of the body composition measurements to hydrostatic percent fat within each age grouping, 22-62, 30-39, 40-49, and 50-59, were highest in the fourth age decade.

7. No significant differences appeared between right vertical and left vertical skinfold measurements.

8. No significant differences appeared between right vertical and right horizontal skinfold measurements.

9. There was a significant difference between the skinfold and circumference measurements, the latter being less accurate in estimating percent fat.

10. The combination of skinfold sites most predictive of percent fat of women in the fourth decade of life was: abdomen, side, anterior thigh, subscapular, suprailliac, and chest.
11. The combination of skinfold sites most predictive of percent fat of women in their fifth decade of life was: posterior knee, bicep, anterior knee, abdomen, subscapular, chin, side, tricep, anterior thigh, and cheek.

12. The combination of skinfold sites most predictive of percent fat of women in their sixth decade of life was: side, posterior thigh, cheek, abdomen, chin, suprailiac, subscapular, anterior thigh, bicep, tricep, and chest.

13. The individual decade skinfold combinations as listed above were more predictive of percent fat than was the whole group formula. The correlations by decade predictions were higher than the whole group by greater than .20.

14. There was no significant difference (.01) between the body composition measurements on the seventh and twenty-first days of the menstrual cycle. Measurements included weight in pounds, hydrostatic percent fat, and Durnin's right vertical skinfolds.

15. The reliability replication of all body composition measurements with nine subjects indicated no significant differences and high correlations.

Conclusions

Body Composition Norms. Current literature indicates one basic pattern of results pertaining to trends in body composition of the adult female population, and that is the ratio of body fat to lean body mass increases with advancing age. Such an increase is said to occur with a
corresponding loss of active (lean) tissue cells, which is generally accepted as a phenomenon of the aging process (Myhre & Kessler, 1966).

Chen (1953), Durnin and Womersley (1974), and Young et al. (1961) studied the body composition of women between the ages of 20 to 60 years and all found increases in percent body fat with age. The norms varied by approximately ± 1% to 4% fat between the studies, and were all slightly higher than the present study by 2% to 5% fat. The magnitude of the increases from one age decade to the next also varied, ranging from + 2% to + 4%, but all reported significant increases in percent fat to occur in the sixth decade. While the present study reports a 5.5% increase, the others reported 4% to 7% increases.

Jackson and Ward (1980) reported similar results to those above, with the exception that the mean percent body fat for each age decade was lower than the other studies. The difference between the studies was as much as 10% fat. The increase in percent fat from one age decade to the next was the largest again after the 40's, at 4.8%.

**Anthropometric Measurements.** Hydrostatic weighing is one of the most accurate methods of measuring body density for assessment of percent body fat. When hydrostatic weighing facilities are unavailable, or time is a factor, skinfold and circumference measurement are simple alternatives. These measurements are used in conjunction with
prediction equations, many of which have been developed for use on the "normal" population.

The predictive values of these equations is very high when used with a population similar to that which were used in the formulation of the particular equation. Conversely, application of equations to different age groups, sexes, races, or individuals of different fitness levels invites large amounts of error (Flint, Drinkwater, Wells, & Horvath, 1977; Jackson & Pollock, 1977; Jackson, Pollock, & Ward, 1979; and Katch & Katch, 1980). The findings of the present study lend evidence to this postulation, as it was found that the skinfold equations were more predictive for the individual age decade groups than for all age groups combined.

The selection and number of anatomic sites most accurate in anthropometric evaluation of body composition is a controversial subject. Equations have been developed utilizing circumferences (McArdle et al., 1981), combinations of girth and skinfold measurements (Damon & Goldman, 1964), and various numbers of skinfold sites (Allen et al., 1956; Durnin et al., 1974; Yuhasz, 1974). Instances of high correlations with densitometric measurements have been reported. The results of the present study indicate the skinfold measurements are much more predictive than circumferences, and that the number and location of sites selected should vary according to age group.

The present study also investigated various techniques
of skinfold measurement including: right vertical skinfolds, left vertical skinfolds, and right horizontal skinfolds. Results indicated that right vertical folds, which was the common procedure throughout the literature, had no more or less predictive value than the other two methods.

**Menstrual Cycle.** Although current literature indicates that body composition may be affected by fluctuating hormone levels associated with the menstrual cycle (Rich & Scherer, 1980; Robinson & Watson, 1968), the present study found no significant difference in measurements taken on the seventh and twenty-first day of the menstrual cycle.

**Replication.** The results of testing subjects a second time correlated highly with the first trial. This indicated reliable testing procedures and thus reliable data.

**Suggestions for Further Research**

1. As the subject sample was not random, this group may not have been representative of their respective age groups. Thus, the predictive skinfold formulae developed from the present study should be applied to a larger similar adult female population to test reliability.

2. Populations of women in their 60's, 70's, and 80's should be similarly evaluated for body composition.

3. The residual lung volume of women in each age group decade should be measured directly, for comparison to estimations. It is possible that an age-related physiological change occurs which could modify the validity of predictive pulmonary methods.
References


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Krahenbuhl, G., Archer, P., & Pettit, L. Serum testosterone and adult female trainability (relationship of serum testosterone to strength, percent body fat, maximal


Rathbun, E., & Pace, N. Studies on body composition. I. Determination of total body fat by means of the body


Womersley, J., Durnin, J., Boddy, K., & Mahaffy, M.  


Yuhasz. The skinfold method of the assessment of lean body mass. Unpublished literature, Exercise Physiology Laboratory of San Diego State University, 1974.
APPENDIX A

- Letter to Participant
- Questionnaire #1
- Questionnaire #2
- Data Collection Sheet
Dear Participant:

Thank you for your interest in this exercise physiology study.

In order to maximize the validity of the research data it is important that several guidelines be followed. Before coming to the lab to be hydrostatically weighed you should:

1) not have eaten in the previous 8 hours.
2) be in a state of normal hydration (do not deprive your body of liquids but please drink only a small amount in the few hours previous to the test.
3) not participate in any exercise the day you are scheduled to be tested.
4) defecate.
5) be scheduled for testing on approximately the 8th day of your menstrual cycle. If you find you have miscalculated your cycle, please call me so that we can reschedule your appointment.

Please bring a two-piece swimsuit so that we can obtain the most valid measure of your body fat.

If you have any questions concerning the study please feel free to ask the technician or call the listed phone numbers. Your participation is greatly appreciated.

Thank you.

Robin Tobin

CSUN office: 885-3242
CSUN exercise physiology lab: 885-3246
home: 886-9990
QUESTIONNAIRE #1

DO NOT FILL IN

Subject #
Additional Tests:
1. replication
2. r.v.
3. cycle

PLEASE PRINT

Name__________________________ Age____(yrs)____(mos)
(last) (first) (MI)

Address_________________________________ ZIP______

Phone (home) ( ) work ( )

Most convenient time to be called (home) ________________
(work) ________________

Days and hours available for testing ________________

Do you regularly participate in any of the following physical activities? If, yes, check:

_____walking _____tennis
_____jogging _____golf
_____swimming _____other (explain)
_____aerobic dance
_____dancing

If you answered yes to any of the above, approximately how much time do you spend per day/week/etc. at this activity? how many mos.
or yrs. on a regular basis

activity hours/day days/week
1.
2.
3.
4.
Are you a menstruating female? yes_______ no_______
If no, explain________________________________________
If yes, is it regular ____________________________
Approximately how many days per monthly cycle?________
What day and month do you expect your next period?
   (month)               (day)

CONSENT FORM

I understand that this test procedure will include my being weighed under water after maximum exhalation and that thirteen skinfold sites will be measured with a spring-loaded caliper. I also understand that at any time during the testing I may discontinue my participation at will.

   Signature __________________ Date ____________

Appointment for H.W.
   time __________ day _______ month __________
Subject #________________

QUESTIONNAIRE #2

1. When was the last time you exercised?________________

2. When was the last time you ate?_____________________

3. Have you been constipated lately?__________________

4. On what day did your period begin this month?_______
NAME__________________________________DATE________________AGE_____
ADDRESS__________________________________PHONE_____________________

MASS (lb)____ X .45 =____(kg) HEIGHT (in)____ X2.5 =____(in)

SITES R. VERTICAL L. VERTICAL RIGHT HORIZ.

1. cheek
2. chin
3. biceps
4. triceps
5. chest
6. suprailliac
7. abdominal
8. side
9. subscapular
10. anterior thigh
11. anterior knee
12. posterior thigh
13. posterior knee

TOTALS RV LV RH

ALLEN (1,2,3,4,5,6,7,8,9,11,13) __________ __________ __________
YUHASZ (4,6,7,9,10,12) __________ __________ __________
DURNIN (3,4,6,9) __________ __________ __________

CIRCUMFERENCES

1. abdomen __________ (A) ____ A + B - C = 19.6 = __
2. rt thigh __________ (B) ____ + ___ - ___ = 19.6 = __
3. rt forearm __________ (C) ____ (3 = 17-26 years,
or __________ ___ (C) ___ 4 = 27-50 years)
4. right calf __________ (C) ___ av. constant

VITAL CAPACITY __________ T°____ BTPS c.f.____ X av ___ = av.

VC ______ BTPS

RV = VC ____ X .280 = ___

HYDROSTATIC WEIGHT tare weight ____ H2O T°____ Db H2O____

1. ___ 2. ___ 3. ___ 4. ___ 5. ___ Av. ____ ± tare ____ = ___
APPENDIX B

- Percent Fat Figures
- Replication Measurements
- Menstrual Cycle Measurements
Legend for Percent Fat Figures

# = subject number
YM = age in years and months
W = weight in pounds
H = hydrostatic fat
A = Allen's % fat
Y = Yuhasz's % fat
D = Durnin's % fat
M_y = McArdle's % fat younger women
M_o = McArdle's % fat older women
1 = right vertical skinfold
2 = left vertical skinfold
3 = right horizontal skinfold
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<th>H</th>
<th>A₁</th>
<th>A₂</th>
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\# = subject number  
D = Durnin's % fat  
W = weight in pounds  
M = McArdle's % fat  
H = hydrostatic % fat  
A = Allen's % fat  
Y = Yuhasz's % fat  
1 = first trial  
2 = second trial
## Menstrual Cycle Measurements

\[ n = 10 \]

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# = subject number  
\( W \) = weight in pounds  
\( H \) = hydrostatic % fat  
\( D \) = Durnin's % fat  
\( 7 \) = 7th day of cycle  
\( 21 \) = 21st day of cycle