THE RELATIONSHIP OF LEAN BODY MASS TO STATIC STRENGTH

by

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A DISSERTATION

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CHAPTER I

INTRODUCTION

Body composition has been the subject of many physiological studies. It has been researched in relation to various physiological areas such as body volume and linearity.[1] Even though studies of body fat and lean body mass have been made, the development of a new instrument for measuring body composition opens up new areas to explore.

It has long been the practice to group students into supposedly homogeneous groups by using criteria such as age, weight, height, sex, or other anthropometric measures. The development of the human body volumeter makes possible a new method of approach to the study of body composition; the volumeter provides a new way to determine the amount of lean body mass a person possesses.

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[1]Leon E. Smith and J. Royce, "Muscular Strength in Relation to Body Composition," Annals of the New York Academy of Sciences, CX (1963), 809-813.

It has been assumed in the past that body weight is the best criterion for placement of students into activities where strength is an important consideration. However, the available literature does not reveal a sizeable, positive correlation between strength and body weight. The human body volumeter provides a way to determine the relationship of lean body mass to strength, and this information could create a whole new procedure that would provide a much more reliable source of information for the placement of students into various physical activities.

Statement of the Problem

The relationship of lean body mass to static strength is the problem this study will attempt to explore.

The Purpose of the Study

This study has two major purposes: (1) to develop a valid and reliable experimental instrument that operates on the basis of water displacement to determine lean body mass, and (2) to determine the relationship of lean body mass to static strength. Static strength was determined by four items on the cable tensiometer test: the shoulder extension, the ankle plantar flexion, the trunk extension, and the knee extension. A secondary purpose of this study is to determine the relationship of lean body mass to height, weight, age, shuttle run, and percentage of lean body mass.

The Need for the Study

In the attempt to build a human body volumeter for use in the research laboratory at the University of Alabama, the rectangular model developed by Allen, Krzywicki, Worth, and Nims at Fitzsimons General Hospital in Denver, Colorado, in 1960, seemed prohibitably expensive to construct. Therefore, with the aid of the University of Alabama School of Engineering, a cylindrical human body volumeter was developed and has various advantages over the rectangular one mentioned above. These advantages will be elaborated on in Chapter III.

The literature on the subject of the relationship of lean body mass to strength is very limited. In the next few years this may be altered since the development of the human body volumeter now provides the researcher with a relatively easy and inexpensive way to determine lean body mass.[2] Even though little study has been done to date on lean body mass as compared to strength, the relationship of body fat to physical fitness has been investigated. Riendeau, using the hydrostatic method to determine body fat, found a significant negative correlation between percent of body fat and selected motor fitness scores.[3] Also, Kireilis and Cureton, using the caliper method of determining body fat, found a significant negative correlation of percent of body fat and the performance of selected motor fitness tests.[4]

Other researchers have compared lean body mass to physical performance items. Leedy concluded that physical performance items where the whole body is forced to move are dependent on percent of lean body mass rather than

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[2] T. H. Allen and others, "Human Body Volumeter Based on Water Displacement," U.S. Army Medical Research and Nutrition Laboratory, Report 250 (September 24, 1960), p. 9.

[3] R. P. Riendeau, "Relationship of Body Fat to Motor Fitness Scores," Research Quarterly XXIX (May, 1958), 200.

[4] Raymond W. Kireilis and Thomas K. Cureton, "The Relationship of External Fat to Physical Education Activities and Fitness Tests," Research Quarterly XVIII (December, 1947), 123-134.

amount.[5] Schifferdecker made a study of college men in the same age bracket and found that those participating in a physical fitness program had ten to twenty percent more lean body mass than those not participating in the program.[6]

With the development of a technique by which total body fat can be estimated, a way is provided by which the relationship between strength and lean body mass can be determined. A need exists for a more effective method for placing students into activities compatible with their strength and abilities. At the present time, the major consideration for placement into activities is based on anthropometric measurements such as height, weight, and age. Since lean body mass can easily be determined, and if there is a strong correlation to strength, this could be a more feasible way to group students into selected activities.

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[5]H. E. Leedy and others, "Relationships Between Physical Performance Items and Body Composition," Research Quarterly XXXVI (October, 1965), 158-163.

[6]G. E. Schifferdecker and others, "Whole Body Radioactivity Measurements and Significance," Journal of Pharmaceutical Sciences LII (1964), 269-272.

Limitations of the Study

(1) The study was restricted to male physical education majors and minors at the University of Alabama.

(2) Only the left side of the body was tested in the strength tests as the norms for the Harrison Clarke Cable Tensiometer Tests, the tests from which the strength items were taken, are set up for the left side of the body.

(3) Left-handed students were not allowed to participate in the study because the strength test items, as described by Clarke, are set up for right-handed students.

Definition of Terms

The following terms will be defined in relationship to their use in the study.

(1) Body density (D) - is frequently called the specific gravity of the body. Density is obtained by dividing the mass by the body volume. $D = \frac{M}{BV}$ [7]

(2) Body volume (BV) - is the amount of water displaced by the subject.[8]

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[7]Elton E. Green, "The Relationship of Lean Body Mass to Strength," (unpublished Ed.D. dissertation, Colorado State College, Greeley, Colorado, 1967), p. 5.

[8]*Ibid*.

(3) Cylindrical human body volumeter - is the tank used to determine the body volume.

(4) Lean body mass (LBM) - is the total body weight of the subject minus the weight of the body fat.

LBM = M - Fat[9]

(5) Residual lung capacity - is the volume of air still remaining in the lungs after the most forcible expiration possible.[10]

(6) Static strength - is the force exerted for a brief period of time where the force is exerted continuously up to a maximum.[11]

(7) Mass (M) - is the normal weight of a subject expressed in kilograms.[12]

(8) Vital capacity - is the breathing capacity of the lungs expressed as the number of cubic centimeters of

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[9] Martin I. Surks and others, "Alteration in Body Composition in Man After Acute Exposure to High Altitudes," Journal of Applied Physiology XXI (November, 1966), 1742.

[10] Techniques for Measuring Body Composition, ed. by Josef Brozek and Austin Henschel (Washington, D.C.: National Academy of Sciences, 1961), p. 96.

[11] Edwin A. Fleishman, The Structure and Measurement of Physical Fitness (New York: Prentice Hall, 1964), p. 130.

[12] Green, "Lean Body Mass," p. 5.

air that can be forcibly exhaled after a full inspiration.[13]

(9) Explosive strength - is the ability to exert maximum energy in one explosive act.[14]

(10) Normal hydration - is the ability of the body to hold a normal amount of water.

(11) Shuttle run - is a test to measure explosive strength.[15]

(12) Kilogram - is 1,000 grams and is equal to 2.2046 pounds.[16]

(13) Centimeter - is 0.01 of a meter and is equal to 0.39 inches.[17]

(14) Millimeter - is 0.001 of a meter and is equal to 0.04 inches.[18]

(15) Liter - is equal to 1.057 quarts.[19]

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[13] Ibid.

[14] Fleishman, Structure and Measurement, p. 130.

[15] Ibid.

[16] Webster's Seventh New Collegiate Dictionary (Springfield, Massachusetts: G&C Merriam Company Publishers, 1965), p. 534.

[17] Ibid.

[18] Ibid.

[19] Ibid.

Basic Assumptions

The researcher assumes that:

(1) Lean body mass is a better predictor of strength than height, weight, or other anthropometric measures.

(2) Lean body mass would be a better way to classify students into homogeneous groups.

(3) Students to be tested will have normal levels of hydration.

Source of Materials

The results of measurements and tests given to sixty male students, majoring or minoring in physical education at the University of Alabama during the spring semester of 1968, provided the subjects for this study.

Methods of Procedure

Each subject was submerged in the human body volumeter to determine his lean body mass. At the same measuring period, two skinfold measures were taken on the dorsum of the right arm and on the right scapula using the Lange Skinfold Caliper. The body weight in kilograms and standing height in centimeters were recorded.

At a later measuring session, the subject was given the cable tensiometer tests to determine static strength as described by Clarke.[20] The shuttle run, as described by Fleishman,[21] was also given to the subjects.

The above data were recorded on a score sheet and a regression analysis procedure[22] was used to determine the relationship of lean body mass to static strength.

The null hypothesis was asserted to answer the following questions:

(1) What is the relationship of lean body mass to static strength?

(2) How effectively can static strength be predicted from knowledge of lean body mass, age, standing height, weight, shuttle run, and percentage of lean body mass?

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[20] Harrison H. Clarke and Theodore G. Scopf, "Construction of a Muscular Strength Test for Boys in Grades 4, 5, and 6," Research Quarterly XXXIII (December, 1962), 515-522.

[21] Fleishman, Structure and Measurement, p. 51.

[22] Deobold B. Van Dalen and William J. Meyer, Understanding Educational Research (New York: McGraw-Hill, Inc., 1962), pp. 365-368.

(3) Does weight contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, height, shuttle run, and percentage of lean body mass?

(4) Does age contribute anything to the prediction of static strength that is not already predicted by lean body mass, height, weight, shuttle run, and percentage of lean body mass?

(5) Does height contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, weight, shuttle run, and percentage of lean body mass?

(6) Does percentage of lean body mass contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, height, weight, and shuttle run?

Organization of the Study

Chapter I of this study gave a broad outline of the entire problem. It attempted to answer the questions concerning what the researcher was trying to do and how he was going to do it.

Chapter II includes a review of the literature pertaining to this study. It discusses the methods that are used to measure body composition and reviews those studies directly related to lean body mass and its relationship to static strength.

Chapter III describes the experimental instrument and the procedures used in carrying out this study. The methods and techniques of collecting the data are described in detail.

When the collection of data was completed, an IBM 360 Model 50 computer was used to tabulate the scores. An analysis of the data was used to determine the relationship of lean body mass to static strength. This information makes up the body of Chapter IV.

Chapter V summarizes the results of the study and makes recommendations for additional studies.

CHAPTER II

REVIEW OF THE LITERATURE

The review of literature is presented in three primary sections. A short introductory section gives some information regarding the relationship of physical activity to body composition. A second section describes techniques for measuring body composition with a brief history of each method included. The third section discusses studies that have been conducted relating specifically to the problem analyzed in this paper, that of the relationship of lean body mass to strength.

The Relationship of Physical Activity to Body Composition

The need for physical activity in order to maintain a healthy body is a well established fact in both medical and educational circles. The intensity of physical activity influences whole-body composition throughout life. This evidence was provided originally by Matiegka, a Czechoslavakian anthropologist, who showed a difference between gymnasts and non-trained individuals in 1921.[1] This problem has been analyzed more systematically over the last twenty years by men like A. R. Behnke and his co-workers who found that players of American football, all physically fit, would have been classified as overweight by previous measuring standards, and thus unfit to serve in the Navy.[2] The high specific gravity of these football players indicated that their bodies contained a small amount of adipose tissue but greatly developed musculature.[3] In this manner the fundamental finding of the marked difference in body composition of trained and non-trained individuals was established. Brozek and Keys and others found in 1957 when comparing men in "active" and "sedentary" occupations, that men performing physical work tend to have, even when their relative body weight is equal, less fat in their organism than men of the

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[1] Human Body Composition, ed. by Josef Brozek (Oxford, England: Pergamon Press, 1965), p. 161.

[2] A. R. Behnke, B. G. Feen, and W. C. Welham, "The Specific Gravity of Healthy Men. Body Weight: Volume as an Index of Men," The Journal of the American Medical Association CXVIII (February 14, 1942), 495-501.

[3] Ibid.

sedentary group.[4] Le Bideau, a Frenchman, presented in 1959 distributions of three skinfolds (and of body density calculated from these skinfolds) for one hundred and thirty students, twenty to thirty years of age, engaged in physical education and athletics; the values for body density were relatively high, ranging from 1.070 to 1.084 g/mm.[5] The matter of the difference in body composition among individuals is a problem deserving attention. The study of body composition could facilitate the clarification of some problems of fitness as regards performance and health.

Techniques for Measuring Body Composition

Since this study is concerned with measuring body composition components, and since one of its major purposes was to construct an instrument for measuring components of body composition, it seems worthwhile at this time to consider some other methods that are employed to obtain the same type of data. This section includes

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[4] Ancel Keys and Josef Brozek, "Overweight Versus Obesity and the Evaluation of Caloric Needs," Metabolism VI (September, 1957), 425-433.

[5] Human Body Composition, p. 100.

information concerning the various techniques used to measure body composition and gives a brief history of each method. It is not the purpose to review in detail the studies selected to illustrate the various techniques, but rather to give a brief, consecutive resume of the progress of research conducted in each area discussed. The study of body composition seems to fall into three major divisions, (1) physical anthropometry, (2) biophysics, and (3) biochemistry. The various methods are discussed in these categories in the following pages.

Physical Anthropometry

The first technique of body composition to be analyzed is in the area of physical anthropometry.

(1) The skinfold method - The skinfold method of measuring body density is accomplished by lifting a fold of skin plus the subcutaneous layer of tissue between the thumb and forefinger, or by having an assistant use both hands to lift a fold, placing a skinfold caliper about one centimeter from the top of the fold, and reading from the scale on the caliper a measurement in centimeters. A variety of sites are possible but taking into

consideration such criteria as accessibility, precision with which the location can be identified and reproduced, and relative homogeneity of the layer of subcutaneous fat, two sites have met with fairly unaminous agreement for the measurement of anthropometric characterization of body composition. These sites are the dorsal skinfold on the upper arm and the subscapula skinfold.[6]

It is impossible to claim clearcut superiority for any particular sites, but the upper-arm site is readily accessible in individuals of both sexes, and the subscapula site has a fairly homogeneous thickness of adipose tissue thus making small differences in locating the site less important than on other areas of the body. For these reasons, it is felt that these two sites should be included in the minimum battery of somatic measurements.[7]

The first mention of measurement of thickness of skin tissues plus skin found in English literature was made by the aforementioned Czechoslavakian anthropologist,

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[6] Techniques for Measuring Body Composition, pp. 14-15.

[7] Committee on Nutritional Anthropometry, Food and Nutrition Board, National Research Council, "Recommendations Concerning Body Measurements for the Characterizations of Nutritional Status," Human Biology XXVIII (May, 1956), 120-121.

Matiegka in 1921.[8] In 1929, a caliper with a spring to provoke "constant" pressure against the skin was used by Franzen.[9] Skinfold measurements have been used in numerour studies since the 1920's, including a study of Puerto Rican children in 1932 by Mitchell, studies conducted at the Iowa Child Welfare Research Station by Meredith in 1935, and a study by Cureton, using procedures standardized by Grover, in 1936 at the University of Illinois.[10] It was found in other studies in the next two decades, markedly by Edwards, Tanner, and Whitehouse in 1954,[11] and Tanner and Whitehouse in 1955,[12] and reported by Le Bideau in 1959[13] that when the Harpenden Skinfold Caliper was used, there were substantial variations in

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[8]Jindrich Matiegka, "The Testing of Physical Efficiency," American Journal of Physical Anthropology IV (September, 1921), 223.

[9]Josef Brozek and Ancel Keys, "Evaluation of Leanness-Fatness in Man: A Survey of Methods," Nutritional Abstracts and Reviews XX (December, 1950), 248-254.

[10]Ibid.

[11]Techniques for Measuring Body Composition, p. 225.

[12]J. M. Tanner and R. H. Whitehouse, "The Harpenden Skinfold Caliper," American Journal of Physical Anthropology XIII Ser. 2 (December, 1955), 743-746.

[13]Human Body Composition, p. 9.

skinfold thicknesses taken on the same area just a few seconds apart. This example illustrates the problem of validating skinfold measurements that have plagued researchers for a number of years. Scores of calipers have been developed, all having various flaws. Finally, one instrument was developed by K. O. Lange in co-operation with Josef Brozek, S. M. Garn, and R. W. Newman that seemed free of the flaws of previous instruments and was not prohibitively expensive; the caliper's pressure at the contact surfaces was kept at the standard value of 10 gm/mm.[14]

It was found by Henry Montoye and others in 1965 that skinfold thickness by pinchcaliper correlates quite highly with fat thickness under the skin at the same height, as determined by surgical incision, r = 0.82, or by means of x-ray, r = 0.61 to 0.90. When hydrostatic weighing has been used as criteron, the skinfold thickness has been shown to give a fair estimate.[15]

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[14] Techniques for Measuring Body Composition, p. 13.

[15] Henry J. Montoye, Frederick H. Epstein, and Marcus O. Kjelsburg, "The Measurement of Body Fatness, A Study in a Total Community," American Journal of Clinical Nutrition XVI (May, 1965), 417-427.

Another study comparing skinfold measurements and weight chart measurements found that the average of the skinfold on the scapula plus the percentage of overweight provided the best estimate of fat content when compared to the skinfold method alone, the overweight method alone, or potassium assessment.[16]

(2) Relative weight method - Relative weight is the standard or average weight of persons of a given height, sex, and age. A set of standards developed in 1912 was replaced in 1957 by Heights and Weights of Children and Youth with a supplement Heights and Weights of Adults in the United States published in 1960. The latter gives the average weight in pounds for each inch of height for eight age groups. The data for these publications were gathered by measuring a large number of people and then averaging the heights and weights according to sex and age to obtain a "standard."[17]

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[16]Guy H. Crook and others, "Evaluation of Skinfold Measurements and Weight Chart to Measure Body Fat," Journal of the American Medical Association CXCVIII, No. 1 (October 3, 1963), 44.

[17]Techniques for Measuring Body Composition, p. 7.

The validity of equations for predicting body fat from relative body weight is limited to a narrow age range. Also, men weighing the same may have different types of musculature. Cureton, in 1947, used chest and ankle girth, height and hip width to measure the percentage of fat in total body weight.[18] This procedure, however, made use of "impure" measurements since chest circumference, which had the highest weight in the prediction equation, was determined not only by skeletal dimensions but also by the layer of subcutaneous fat.[19] In physically active people, a larger fraction of body weight will be muscle mass than in less active people though the weight may be the same. Brozek, in 1954, found this to be true with a study of matched business and professional men; the more active men, though heavier and relatively overweight, were leaner.[20] Parizkova, in 1959, found little difference in the average heights and weights of normally active girls

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[18] Brozek and Keys, Nutritional Abstracts, p. 249.

[19] Ibid.

[20] Techniques for Measuring Body Composition, p. 10.

and of gymnasts; at the same time, the layer of subcutaneous fat was markedly thinner in gymnasts, the mean for ten sites being 9.0 mm in gymnasts to 12.3 mm in girls.[21] This finding illustrates the importance of body composition parameters other than height and weight. Louise Kindig at Temple University in 1967 found that anthropometric measurements (height, weight, width, and girth) had low negative correlations with body density ranging from .022 to .459.[22]

In the light of these findings, relative body weight has severe limitations. The majority of the population deviates in some degree from the standard weight for age, sex, and height, and it is in this range that relative weight is least reliable as a criterion of leanness or fatness, and its discriminatory power must be supplemented by more direct measures. The dependability of traditional relative weight decreases as the heterogeneity of the population,

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[21] Human Body Composition, p. 100.

[22] Louise E. Kindig, "Estimation of Body Fat of College Women from Densiometric and Anthropometric Measurements," Dissertation Abstracts XXVIII (Ann Arbor, Michigan: University Microfilms, July, 1967), 952a-953a.

genetic and occupational, increases.[23]

(3) Radiographic method - Radiography is a method of determining subcutaneous tissue by the study of x-rays. Since radiography involves the differentation of the fat-plus skin layer from underlying tissue, relatively light, low milliamperage "soft tissue" exposures suffice. Using high speed film, such as DuPont type 508, paraspeed screens and a peak kilovoltage of thirty plus twice the part thickness in centimeters, adequate six foot films are obtained at 7-15 MAS depending on the need for visualizing bony landmarks. Higher exposures and denser radiographs can be used if an adequate viewing device is available. Thus lateral-skull plates made in routine cephalometry and standard chest x-rays can be studied. However, it is desirable to set up techniques specifically for fat tissue work, adjusting the milliamperage and kilovoltage to produce easily measurable film with maximum shadow differentation. The preferred sites for radiography are the lower thoracic, iliac, and trochanteric portions of the body. In some studies, of course, the problem may dictate the site.[24]

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[23] Techniques for Measuring Body Composition, p. 11

[24] Ibid., pp. 37-41.

The credit for the first use of systematic analysis of x-ray techniques goes to the pediatrician Harold Stuart in 1940-1942; Stuart introduced the linear measurements of fat thicknesses and the weighing of the separated fat-shadow.[25] These methods were later employed by Reynolds in a series of studies related to growing children: Reynolds, 1944;[26] Reynolds, 1946;[27] Reynolds and Clark, 1947;[28] Reynolds and Schoen, 1947;[29] and Reynolds and Asakawa, 1948.[30] Since 1953, S. M. Garn and his

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[25]Harold C. Stuart and Penelope Hill Dwinell, "The Growth of Bone, Muscle and Overlying Tissues in Children Six to Ten Years of Age as Revealed by Studies of Roentgenograms," Child Development XIII, No. 3 (September, 1942),195-213.

[26]Earle L. Reynolds, "Differential Tissue Growth in the Leg During Childhood," Child Development XV (December, 1944), 181-204.

[27]Earle L. Reynolds, "Sexual Maturation and the Growth of Fat, Muscle, and Bone in Girls," Child Development XVII (September, 1946), 121-143.

[28]Earle L. Reynolds and Leland C. Clark, "Creatinine Excretion, Growth Progress and Body Structure in Normal Children," Child Development XVIII (December, 1947), 155-166.

[29]Earle L. Reynolds and Grace Schoen, "Growth Patterns of Identical Triplets from 8 through 18 Years," Child Development XVIII (September, 1947), 130-144.

[30]Earle L. Reynolds and Toshiko Asakawa, "The Measurement of Obesity in Childhood," American Journal of Physical Anthropology VI, Ser. 2 (December, 1948), 475-486.

colleagues have conducted an extensive series of studies using the radiographic techniques: Garn and Clark, 1953;[31] Garn and Gorman, 1956;[32] Garn and Young, 1956[33] and Garn, 1957.[34] Harrison Clarke,[35] and Brozek, Mori, and Keys,[36] are also included among others in an index of researchers using x-ray methods of studying body composition. Ruth V. Harper found a correlation of 0.88 between fat-shadow measurements and fat-caliper measurements; this indicates

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[31]Stanley M. Garn and Leland C. Clark, "The Sex Difference in the Basal Metabolic Rate," Child Development XXIV (September-December, 1953), 215-224.

[32]Stanley M. Garn and Edward L. Gorman, "Comparison of Pinch-Caliper and Teleroentgenogrammetric Measurements of Subcutaneous Fat," Human Biology XXVIII (September, 1956), 407-415.

[33]Stanley M. Garn and Richard W. Young, "Concurrent Fat Loss and Fat Gain," American Journal of Physical Anthropology XIV (September, 1956), 497-504.

[34]Stanley M. Garn, "Roentgenogrammetric Determinations of Body Composition," Human Biology XXIX (September, 1957), 337-353.

[35]Harrison H. Clarke and others, "Comparison of Upper Arm Measurements by Use of Roentgenograms and Anthropometric Techniques," Research Quarterly XXVII (December, 1956), 379-385.

[36]Josef Brozek, Hiroyoshi Mori, and Ancel Keys, "Estimation of Total Body Fat from Roentgenograms," Science CXXVIII (October 17, 1958), 901.

validity but the final test of x-ray measurements must come from actual dissection and tissue analyses.[37]

Among the disadvantages of the radiographic technique must be listed the exposure to radioactive rays. Another consideration is the expensive equipment involved in such a technique, thus making it impractical for certain types of studies.

(4) Surface area techniques - The introduction of mathematical techniques to direct surface area measurements led to the development of geometric methods, whereby surface area is estimated by assuming that parts of the body more or less resemble regular geometric solids. To avoid tedious and time consuming direct measurements, workers have turned to the development of formulae, theoretical and empirical, for calculating surface area from its geometric relations to the major dimensions of the body, height and weight.[38]

Surface area techniques have been employed as early as 1793 with Abernathy's estimate.[39] Many studies have

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[37] *Techniques for Measuring Body Composition*, p. 46.

[38] *Ibid.*, pp. 59-66.

[39] *Ibid.*

been made since that time, but the trend of thought today is that surface area, as a metabolic reference standard, owes its validity to its good correlation with body composition as determined by studies conducted by Miller and Blyth, 1953; Brozek and Keys, 1953; and Best and Kuhl, 1953.[40] Johnston and Bernstein, 1955,[41] and Behnke, 1953[42] were also included in this group. This theory has been extended by Garn, Clark, and Portray by the suggestion that lean body mass owes its importance to its major constituent, namely skeletal muscle mass or size.[43] According to Best and Kuhl, body muscle constitutes the largest single component of the "active protoplasmic mass" which Behnke and Siri in 1957 identify with lean body mass.[44]

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[40] Ibid.

[41] Louise C. Johnston and Lionel M. Bernstein, "Body Composition and Oxygen Consumption of Overweight, Normal and Underweight Women," The Journal of Laboratory and Clinical Medicine XLV, No. 1 (January, 1955), 109-117.

[42] A. R. Behnke, "The Relationship of Lean Body Weight to Metabolism and Some Consequent Systematizations," Annals of the New York Academy of Sciences LVI, Art. 6 (November 17, 1953), 1095-1142.

[43] Techniques for Measuring Body Composition, p. 65.

[44] Ibid.

In the last several years there has been a flight away from surface area techniques, and it is obvious that current thought does not include it as a method or technique of estimating body composition in the sense of other measurements. It may well be that surface area should be referred, as suggested by Behnke and Siri, to lean body mass rather than gross weight.[45]

(5) Anthroscopic or photoscopic method - Anthroscopy or photoscopy is a method of analyzing body composition on the basis of visual appraisal - either by direct inspection or preferably by the study of photographs. A system of "body typing" was developed by W. H. Sheldon in 1940[46] and in 1954[47] in which man's physique is characterized in terms of three components, endomorphy, mesomorphy, and ectomorphy.

At the Laboratory of Physiological Hygiene at the University of Minnesota, a group of young men were

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[45]Ibid., pp. 64-66.

[46]William H. Sheldon, The Varieties of Human Physique (New York: Harper and Brothers Publishers, 1940).

[47]William H. Sheldon, Atlas of Men (New York: Harper and Brothers Publishers, 1954).

photographed under control conditions and after losing one fourth of their body weight. Two independent sets of ratings of somatype were obtained, based on inspection of the pictures of the men in the nude, in three positions. Both sets of ratings indicated a marked decrement in endomorphy, slight decrease in mesomorphy, and a marked decrement in ectomorphy.[48]

Using the information from Lasker's study, Brozek formed an equation for predicting density from ratings of endomorphy. Using these ratings as calculated by Brozek in 1955, endomorphy ratings, as made by competent investigators, correlated with densiometric estimates of fat content.[49]

Parnell, in 1958, presented a scheme which made use of a combination of physical anthropology and photoscopy; somatometric data should, he felt, help provide a more precise definition of the components and add objectivity

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[48]Gabriel Ward Lasker, "The Effects of Partial Starvation on Somatotype," American Journal of Physical Anthropology V, Ser. 2 (September, 1947), 323-333.

[49]Josef Brozek, "Role of Anthropometry in the Study of Body Composition: Toward A Synthesis of Methods," Annals of the New York Academy of Sciences LXII, Art. 4 (November 28, 1955), 491-504.

that was lacking in photoscopy. Parnell replaced Sheldon's terms with his own, Fat, Muscularity, and Linearity. It must be noted that he included bone or skeletal weight within muscularity, a concept deeply intrenched in human body study but in need of revision in the light of new research in bone mineralization.[50]

Various other studies have been made in the area of photogrammetry and photography, among them studies by Tanner and Weiner, 1949,[51] and by Hunt and Giles in 1956.[52]

It is felt by Brozek that there is a need for a systematic effort to do some elementary things in order to put the visual and photographic appraisal of body composition on a sound methodical basis. These include the development of a check list or rating scales and a system of quantitative appraisal of photographs, using

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[50] Ibid.

[51] J. M. Tanner and J. S. Weiner, "The Reliability of the Photogrammetric Method of Anthropometry, With a Description of a Minature Camera Technique," American Journal of Physical Anthropology VII, Ser. 2 (June, 1949), 145-186.

[52] Edward E. Hunt, Jr. and Eugene Giles, "An Evaluation of the Photo-metric Camera," American Journal of Physical Anthropology XIV(September, 1956), 429-436.

objective criteria of body composition for purposes of validation; to provide an album of photographs to serve as a guide and reference; to establish for specified population groups, the equations for predicting body composition from photoscopic and photogrammetric data, and to determine the magnitude of the errors associated with such estimates.[53]

Biophysical Techniques

The second category of body composition studies to be discussed will be those that are categorized under biophysics.

(1) Gas dilution method - The gas dilution method for measuring body composition is well suited for children, aged persons, patients, or animals since no discomfort or active participation is required by the subjects. The subject, wearing only a standard hospital gown, is placed in a chamber, a rigid structure that will not vary in volume. Five to ten minutes are required for the subject's metabolic rate and chamber gas composition to stabilize. The chamber volume is then subtracted from the tissue volume of the subject. Helium from a second chamber is then

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[53] Techniques for Measuring Body Composition, p. 5.

mixed with the air in the first chamber and after equilibration, the concentration of helium and the volume of the subject are related by use of a formula.[54]

Helium dilution was used in a study by Norris of age changes in men using the apparatus developed by Siri in 1956 with some modifications. Replicate determinations were made and body density was obtained from the ratio total body weight-total body volume. Results indicated a constant variability of measurement not associated with the size of the objects measured.[55]

Studies have been attempted at the University of Louisville Medical School, Louisville, Kentucky,[56] and the State University of Iowa,[57] both in 1963, to determine the body volume of infants, but both have also met with negative results. The Louisville researchers had mechanical problems with their apparatus, but the technique shows

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[54] Ibid., pp. 108-117.

[55] Annals of the New York Academy of Sciences, CX, pp. 623-627.

[56] Ibid., pp. 75-79.

[57] Ibid., pp. 80-90.

promise. The gas dilution technique must still be regarded in the experimental stage with no reliable data as of this date.[58]

(2) Underwater weighing - Underwater weighing or specific gravity are terms applied to the method of determining body density by obtaining the difference between body weight in the air and weight of the fully submerged body. This technique functions on the basis of the Archimedian principle that a body immersed in water loses weight by an amount equal to that of the weight of the water displaced by it. Underwater weighing systems can be divided into two categories, (1) suspension, and (2) platform. With the suspension system, more widely used, the subject is lowered underwater by means of a hoist. According to Brozek in Techniques for Measuring Body Composition only one platform system is in operation in the United States, and it is located in Natick, Massachusetts. With this device, the subject sits in a chair anchored to a scale platform and immerses himself by leaning forward until he is underwater. Density, in both

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[58] Techniques for Measuring Body Composition, p. 108.

systems, is obtained by subtracting the Volume, obtained by water displacement, from Mass, the weight of the subject in the air. Corrections are made for residual volume and gas in the gastrointestinal tract. Then, using a simple formula, body density is determined.[59]

Attempts to find specific gravity were made as early as the middle of the eighteenth century by Robertson in 1757,[60] and work done up to 1933 was reviewed by Boyd in that year.[61] Unfortunately, most of the early data had to be discarded because of lack of standardization and failure to correct the weight of the body underwater for air in the lungs and air passages. In its application to man, the idea of using specific gravity as an indication of fatness was developed by A. R. Behnke in 1941 and 1942.[62] In 1942, using the water displacement techniques and

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[59] Ibid., pp. 90-104.

[60] Brozek and Keys, "Evaluation of Leanness-Fatness," p. 252.

[61] Edith Boyd, "The Specific Gravity of the Human Body," Human Biology V, No. 4(December, 1933), 646-672.

[62] Behnke, "Specific Gravity of Healthy Men," pp. 495-501.

correcting for residual air, Behnke, Feen, and Welham measured the specific gravity of ninety-nine healthy men in military service, twenty to forty years of age. The mean for this group was 1.0684.[63]

Equipment has been set up and studies made at various places throughout the country in the last decade, notably at the University of Minnesota where Brozek and Keys did extensive work,[64] and at Cornell University where studies in fatness and weight reduction were carried out by Young and others in 1962,[65] and by Young and DiGiacomo in 1965.[66]

A study of replicability of the underwater weighing method for determining density was made by Durnin and Taylor in 1960, and the standard error of a single observation was 0.0023 units of density. The validity of the

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[63] Ibid.

[64] Techniques for Measuring Body Composition, pp. 256-262.

[65] Charlotte M. Young and others, "Predicting Specific Gravity and Body Fatness in Young Women," Journal of the American Dietetic Association XL (February, 1962), 102-107.

[66] Charlotte M. Young and Maria M. DiGiacomo, "Protein Utilization and Changes in Body Composition during Weight Reduction," Metabolism XIV (October, 1965), 1084-1093.

estimation of fat content of the body from body density or specific gravity has been demonstrated by correlating this value with the fat content, expressed as percentage of weight, of the eviscerated carcass. Studies of this type have been reported for guinea pigs (Babineau and Page, 1955), swine, sheep (Kirton and Barton, 958) and cattle. Barton and Kirton reported r = 0.877 between reciprocal of specific gravity and the percentage of fat in half-carcass sheep.[67]

A disadvantage of underwater methods is that it requires fifteen to twenty minutes per measurement thus causing relatively slow procedure.[68] The subjects must be semi-trained since it requires considerable practice, as many as eight to ten practice sessions underwater, before the subjects are able to expel residual air to a maximum.[69] Also, corrections in the formula for determining

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[67] *Techniques for Measuring Body Composition*, pp. 260-261.

[68] *Ibid*., p. 103.

[69] Frank I. Katch, "Apparent Body Density and Variability During Underwater Weighing," *Research Quarterly* XXXIX (December, 1968), 997.

body density by hydrostatic weighing may be necessary in the light of new findings in bone mineral studies.[70]

Biochemical Techniques

Various biochemical techniques are employed in determining body composition including creatinine coefficient studies, bone mineral studies, potassium assessment studies, water and electrolyte studies, and basal oxygen studies. Potassium assessment could rightfully belong under the topic of water and electrolyte methods, but since it alone has been the subject of rather concerntrated study, it will be discussed as a separate technique.

(1) Creatinine coefficient - Creatinine is the argument that excretion of creatinine can be taken as an index of muscle or "active tissue." Talbot in 1938 concluded that the creatinine coefficient calculated as the ratio of the twenty-four hour excretion of creatinine in milligrams to the bodyweight in kilograms is an accurate index of obesity. Various studies have been made using this method, one being in 1952 by Miller and others in

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[70] Human Body Composition, p. 9.

which he estimated lean body mass from oxygen consumption and creatinine excretion.[71]

Another study was made by Novak in 1963 in which age and sex differences in body density and creatinine excretion of high school children were explored. It was found that formulae for adults could not be correctly applied to children. Although the body density and the creatinine excretion in adolescent boys and girls approximate the values determined for adults, the proportions of the total body fat to the fat-free mass, as indicated by body density were not necessarily the same in adults and children.[72]

Best, Kuhl, and Consolazio found in 1953 that "the creatinine coefficient, though a valid measure of obesity, is not as accurate as simpler anthropometric measures."[73] The value of the creatinine coefficient as an indicator of body composition was examined by Garn and Clark in 1955 and low negative correlations, r = 0.40, were obtained between the creatinine coefficient and body fat; it was

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[71]Brozek and Keys, "Evaluation of Leanness-Fatness," p. 248-254.

[72]Annals of the New York Academy of Sciences, CX, pp. 545-573.

[73]Techniques for Measuring Body Composition, p. 268.

felt that on the basis of these data, the creatinine coefficient could not be regarded as a sensitive measure of fatness.[74] These various uncertainties that have developed over the years have made many researchers feel that validity of creatinine coefficient is wanting.

(2) Bone mineral method - Bone mineral studies are attempts to estimate skeletal weight and to measure bone mineralization. The concept of muscle and bone interdependence became accepted in human biology as indicated by Sheldon's concept that mesomorphy, his second somatotype component, consisted of concommitantly varying amounts of muscle and bone,[75] and by Keys' and Brozek's assumption in 1953 that bone mineral formed a constant percentage of body weight.[76] A number of recent publications on bone mineral research have failed to show an important degree of relationship between muscle and bone; it is evident now that bone mineral content varies.[77] Important information was

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[74] Ibid., p. 248.

[75] Sheldon, Varities, p. 5.

[76] Techniques for Measuring Body Composition, p.69.

[77] Ibid., pp. 69-70.

provided in a series of studies directed by Mildred Trotter at Washington University School of Medicine indicating that skeletal density shows a significant decrease during late maturity and old age,[78] as well as significant race (higher in Negroes, male and female than in whites),[79] and sex (higher in males) differences.[80]

Two laboratories that participated in researches on bone composition, initiated by Mack in 1939-1949,[81] are the Biophysics Laboratory of Pennsylvania State University[82] and Nelda Stark Laboratory for Human Nutritional Research, Texas Women's University in Denton, Texas.[83] In Texas, Mack's radiographic photometric method for the

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[78]Mildred Trotter, "A Preliminary Study of Estimation of Weight of the Skelton," American Journal of Physical Anthropology XII, Ser. 2 (December, 1954), 537-552.

[79]Human Body Composition, p. 9.

[80]Ibid.

[81]Pauline Beery Mack and others, "A Method for Estimating the Degree of Mineralization of Bones from Tracings of Roentgenograms," Science LXXXIX (May 19, 1939), 467.

[82]Paul T. Baker and Harald Schraer, "The Estimation of Dry Skeletal Weight by Photometry of Roentgenograms," Human Biology XXX, No. 3 (September, 1958), 171-184.

[83]George P. Vose and Albert L, Jubala, Jr., "Bone Strength - Its Relationship to X-ray Determined Ash Content," Human Biology XXXI, No. 3 (September, 1959), 261-269.

assessment of the mineral content of bone was further developed and its precision increased. Vose, in 1959, using x-ray techniques on one anatomical site, the distal femur along the bipecondylar diameter, found that in fifty percent of the subjects tested, the bone mineral content varied between 12.0 and 14.9 percent, the total range being nine to twenty percent.[84]

The variability of bone density could affect the estimation of fat by body density. The error will not affect x-ray or skinfold techniques, but rather may make them better indicators of total body fatness than has been suggested by their correlation with body density. Bone mineral variability does not have much significance in the measurement of body composition change.[85]

(3) <u>Potassium assessment method</u> - The potassium 40 method involves measurement by gamma ray emission the concentration in the body of the naturally occurring isotope.[86]

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[84] _Ibid_.

[85] _Techniques for Measuring Body Composition_, pp. 73-74.

[86] Eva D. Wilson and others, _Principles of Nutrition_ (New York: John Wiley and Sons, Inc., 1959), p. 371.

The present knowledge of whole body potassium as related to body components is insufficient. Studies conducted so far have been restricted almost entirely to the analyses of meat cuts from sheep and cattle and of live sheep. The correlation between K^{40} count rates per unit of weight and percentage of separated morphological components were less than 0.90 for meat cuts and less than 0.80 for live animals. The correlation coefficients between potassium content per unit of weight of meat cuts from pigs or lambs and chemical composition in terms of water or protein were always higher, close to 1.00. Therefore, total body potassium should be interpreted in terms of chemical body composition. Muscle mass represents a large part of total body weight and most of the total body potassium is concentrated in muscles.[87]

Improvements in the method for determining exchangeable potassium in mass in the form of highly sensitive "whole body counters" are important steps since Brozek and others propose to measure total body water and exchangeable potassium as basic variables in body composition studies.

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[87] Human Body Composition, pp. 57-60.

Fat-free solids can be estimated from the value of exchangeable potassium; fat-free solids plus total body water yield fat-free body weight. Total fat will equal the difference between total weight and fat-free body weight.[88]

One of the most recent studies regarding potassium assessment was made at the University of Illinois in 1967. In this study, a comparison of techniques, hydrostatic weighing, potassium assessment, and whole body counting, was made and it was found that potassium assessment yields estimates of the amount of fat which were comparable to body density for the age group studied. Regression equations for predicting grams of potassium in the human body were also constructed.[89]

The basic problem in measuring potassium content of the intact animal is that of measuring potassium in an unknown and variable manner and in containers of varying sizes. Since the size and shape of the body vary from person to person and the potassium is not uniformly

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[88] Techniques for Measuring Body Composition, p. 264.

[89] Frank Harvey Murphy, "A Comparison of Techniques for Estimating the Amount of Fat in the Human Body: The Regression of Equations for Predicting the Amount of Potassium in the Human Body," Dissertation Abstracts XXVIII (Ann Arbor, Michigan: University Microfilm, 1967), 1284-1285.

distributed, it is not yet possible to accurately measure potassium content in whole body composition.[90]

(4) Water and electrolyte methods - The water and electrolyte methods of studying body composition include the analysis of such aspects of body composition as sodium content and distribution, potassium content and distribution, and chloride content and distribution, as well as information on blood and body water.[91] This involves tracer techniques to study water and electrolyte physiology. These techniques were employed in 1946 by Moore,[92] and 1952 by Edleman and others;[93] other studies by Edleman and his colleagues were conducted in 1954,[94] and in 1958.[95]

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[90] Annals of the New York Academy of Sciences, CX pp. 175-176.

[91] Techniques for Studying Body Composition, pp. 140-147.

[92] F. D. Moore, "Determination of Total Body Water and Solids with Isotopes," Science CIV (August, 1946), 157-160.

[93] I. S. Edleman and others, "Body Composition: Studies in Human Beings by Dilution Principle," Science CXV (April 25, 1952), 447-454.

[94] I. S. Edleman and others, "Body Sodium and Potassium. IV. The Normal Exchangeable Sodium, Its Measurement and Magnitude," Metabolism III No. 6 (November, 1954), 530-538.

[95] I. S. Edleman and others, "Interrelation Between Serum Sodium Concentration, Serum Osmolarity and Total Exchangeable Sodium, Total Exchangeable Potassium, and Total Body Water," Journal of Clinical Investigation XXXVII No. 9 (September, 1958), 1236-1256.

Detailed comparison of the methods involving dilution of antipyrine and of deuterium oxide were made by Freeman and others in 1955; the tabulated results indicated better agreement using deuterium oxide than antipyrine.[96] McMurrey and others in 1958 found that within forty-eight hours determinations can be made of red cell volume with Cr^{51}, plasma volume with Evans Blue Dye, total body water with deuterium oxide, extracellular volume with Br^{82}, total exchangeable sodium with Na^{24}, and total exchangeable potassium with K^{42}.[97] Paired studies have been made, using electrolyte methods, to show a comparison of patients during and after illness; such studies show the actual dimension of compositional change involved in illness and recovery.[98] With Edleman and McMurrey, researchers in biochemical work

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[96] Human Body Composition, p. 15.

[97] James D. McMurrey and others, "Body Composition: Simultaneous Determination of Several Aspects by the Dilution Principle," Metabolism VII No. 5 (September, 1958), 651-677.

[98] Annals of the New York Academy of Sciences, CX, pp. 978-982.

include Robinson,[99] Forbes and Lewis,[100] and Rundo and Sagild.[101] In addition to the early work done by Moore, studies were done by Pace,[102] Steele,[103] and Osserman[104] in the late 1940's and 1950's.

(5) Basal Oxygen consumption - This method concerns the measurement of the basal oxygen consumption of individuals by means of a clinical machine. Even though the measurement of general metabolic processes as expressed per unit of surface area has been considered the best available index, there is an increasing body of evidence that tends to indicate that active tissue or some closely

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[99] James R. Robinson, "Metabolism of Intracellular Water," Physiological Review XV, No. 1 (January, 1960), 112-149.

[100] Gilbert B. Forbes and Anne M. Lewis, "Total Sodium, Potassium and Chloride in Adult Men," Journal of Clinical Investigation XXXV, No. 2 (May, 1956), 596-606.

[101] J. Rundo and U. Sagild, "Total and Exchangeable Potassium in Humans," Nature CLXXV (April 30, 1955), 774.

[102] Nello Pace and others, "Studies on Body Composition. IV. Use of Radioactive Hydrogen for Measurement in vivo of Total Body Water," Journal of Biological Chemistry CLXVIII No. 2 (May, 1947), 459-469.

[103] J. Murray Steele and others, "Total Body Water in Man," American Journal of Physiology CLXII No. 1 (July, 1950), 313-317.

[104] Techniques for Measuring Body Composition, p. 140.

related measure such as lean body mass might be superior to surface area for the estimation of basal oxygen; it has been suggested that basal oxygen consumption be used as the reference standard for evaluating other estimates of active protoplasmic mass.[105]

Studies conducted concerning basal oxygen consumption include one by Louise Johnston and Lionel Bernstein who found in a study of overweight, normal, and underweight women, with basal oxygen being measured by a clinical machine called a Metabulor, that oxygen consumption was found to be equally well correlated with surface area, lean body mass, and cell mass.[106] Garn in a study comparing the basal metabolic rate in girls and boys found the oxygen consumption level higher in boys than in girls but concluded that this was not due entirely to the greater body size or higher proportion of muscle per unit mass.[107]

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[105] Methods for Evaluation of Nutritional Adequacy and Status, ed. by Harry Spector and Martin S. Peterson (Washington, D. C.: National Academy of Science, 1954, pp. 286-292.

[106] Johnston, "Oxygen Consumption of Overweight, Normal and Underweight Women," pp. 104-117.

[107] Garn, "Sex Differences in Metabolic Rate," pp. 215-224.

It has since been determined that basal metabolic rate expressed per weight unit of active mass, tends to be the same in both sexes.[108] Charlotte Young and her associates conducted a study concerning basal oxygen consumption as a predictor of lean body mass in young women and found the mean estimate to be higher than those calculated from specific gravity measurements; thus basal oxygen consumption did not appear to be particularly useful in predicting lean body mass.[109] Basal oxygen consumption was included in a group of methods used by Norris and others in 1963 in studying age changes in men.[110] Basal oxygen showed a significant reduction with increasing age; however, when basal oxygen consumption per liter of intracellular water was calculated, the average values were 8.5 and 8.9 millimeters and age differences were not judged to be significant.

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[108] _Techniques for Measuring Body Composition_, p. 174.

[109] Charlotte M. Young and others, "Basal Oxygen Consumption as a Predictor of Lean Body Mass in Young Women," _Journal of the American Dietetic Association_ XLIII (August 1963), 128.

[110] _Annals of the New York Academy of Sciences_, CX, pp. 623-632.

As with other areas of study concerning body composition, basal oxygen consumption techniques are constantly undergoing developmental changes. As simple, reliable methods of the quantification of body composition gain more acceptance, they should lead to more precise establishment of physiological norms.[111]

Chemical Analysis

There is one other method of determining body composition that does not fall into the aforementioned categories. This method is direct chemical analysis.

Chemical analysis - Chemical analysis, the dissection and analysis of cadavers, is still the best way to determine the composition of whole bodies, but it is difficult for several reasons such as the unwillingness of relatives to give bodies, the distastefulness of the job and the immediacy of the task. It is particularly difficult to obtain the bodies of healthy people, for sudden death carries with it legal complications.

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[111] Evaluation of Nutritional Adequacy, p. 292.

The first knowledge about chemical composition of the adult body was obtained from figures published by three different German authors in the 1870's and 1880's; these studies found 65.7 percent water and 4.7 percent ash in the body of a man who weighed 62.5 kilograms.[112] This was the only available knowledge about chemical composition of the whole adult body until 1945 when H H. Mitchell and his colleagues published their findings; Mitchell, Hamilton, Staggerda, and Bean found in the biochemical study of one body conducted at the University of Illinois that 12.5 percent of bodyweight was extractable fat; of this 45 percent was adipose tissue, 20 percent from the skelton, 8 percent from skin, 8 percent from the liver, and 3 percent from the brain.[113] They also gave values for the amounts of water, ether-extractable material, nitrogen, calcium, and phosphorus from the body of this thirty-five year old man.[114] Research conducted in the present century

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[112]Human Body Composition, pp. 31-43.

[113]H. H Mitchell and others, "The Chemical Composition of the Adult Human Body and Its Bearing on the Biochemistry of Growth," Journal of Biological Chemistry CLVIII No. 3 (May, 1945), 625.

[114]Ibid.

reveals some interesting facts about the chemical composition of the body. In the bodies of a man and a woman who did not die from disease and who were only 84 and 70 percent of their standard weight for height, the percent of fat was 19.4 and 23.6 percent respectively.[115]

Fat is the constituent that shows the greatest variability from one person to another, and the percentage of water is inversely related to the percentage of fat.[116] Some of the more recent chemical analyses of bodies are those of Fee and Weil in 1960 which concerned the bodies of babies of diabetic mothers.[117] Since the bodies of infants are a more manageable size, more and more researchers are turning to infant analyses.

Direct analyses provide the fundamental reference point for the indirect methods for analyzing body composition, and the importance of these studies should be emphasized. For reasons listed above, chemical analyses studies are available in limited number.

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[115] Human Body Composition, pp. 31-43.

[116] Ibid.

[117] Annals of the New York Academy of Sciences, CX, pp. 869-895.

The methods of analyzing body composition have progressed through the years, from simple physical measurements to more sophisticated, biochemical processes that require expensive equipment and trained personnel. Each method has merit and has formed a step in the march of body composition studies. Some have suffered discreditment and a falling away, but most still represent valid techniques, and each has particular areas of study to which it is best suited.

The methods of studying body composition most closely related to the present study are those two that fall under the category of biophysics, the gas dilution method, and the underwater weighing method. These two techniques involve physical apparatuses and procedural techniques closely resembling those of the present study which employs the method of using water displacement to measure body composition components. The water displacement method is perhaps better suited to lay experiments than either of the other biophysical techniques, since less equipment, training, and thus expense are needed to facilitate body composition research.

Studies Concerning the Relationship of Lean Body Mass to Strength

The last major division of this chapter deals with research conducted that relates specifically to the subject of lean body mass and its relationship to strength. A search through the literature reveals that several studies compared human body composition to physical performance and muscular strength. These studies generally agree that the ratio of lean body mass to total body weight is of great significance to physical educators as well as to the individual learner.

H. E. Leedy and his associates tried to determine the predictability of lean body mass from physical performance and related items, and they found their correlation to be significant. However, when using the correlation figure, the estimation of lean body mass from the data on the physical performance and related items would be subject to large error.[118]

To the best knowledge of this writer, three studies have been reported which compare lean body mass to

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[118]Leedy, "Performance Items and Composition," pp. 158-163.

strength. A study by Laubach and McConville made a comparison of lean body mass to four strength items: trunk flexion, hip flexion, hip extension, and trunk extension. The conclusion from this study was that lean body mass, as calculated from skinfold caliper measurement, has no significant advantage over body weight as a criterion for comparing the four muscle groups.[119]

Leon Smith and J. Royce, in a study using hydrostatic techniques, found in 1963 that a correlation of 0.38 between leg strength and lean body weight was statistically significant at the five percent level. But they also found that the use of lean body weight as a criterion for predicting leg strength had no advantage over the use of body weight.[120]

Elton Green, in a study using volunteers of varying ages, attempted to determine lean body mass, as measured by the human body volumeter, to static strength, as measured by the cable tensiometer, and found that lean body

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[119] Lloyd L. Laubach and John T. McConville, "Muscle Strength, Flexibility, and Body Size of Adult Males," Research Quarterly XXXVII (October, 1966), 384-392.

[120] Smith, "Strength and Composition," p. 810.

mass is a significantly better predictor of total static strength than chance at the .01 level. However, it only accounted for thirty-eight percent of the variability, which is too low to merit its use.[121]

Results from studies on the relationship of lean body mass to strength reveal no significant information to merit its use over total body weight. The studies, however, are very limited in number, and there has not been enough research done using specific population groups to form any positive conclusions. Further research in this area may reveal a greater significance of lean body mass as related to strength than has been found in the past.

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[121]Green, "Lean Body Mass," p. 30.

CHAPTER III

PROCEDURES AND TECHNIQUES

The purpose of this study is to develop an experimental instrument and to establish the relationship of lean body mass to static strength, and the methods and procedures used to accomplish this purpose will be discussed in this chapter.

Methods of Procedure

Each subject was given an appointment to report to the research laboratory to be submerged in the cylindrical human body volumeter to determine his lean body weight. (See Appendix B). During the same measuring period, the subject's total body weight in kilograms, age to the nearest birthdate, and standing height in centimeters were recorded on a score sheet. Several skinfold measures were taken on each of the two selected sites, the dorsum of the right arm and the right scapula. These measurements were recorded in millimeters using the Lange Skinfold Caliper. An average of these measurements was figured for each site, and this figure was recorded on the score sheet. (See Appendix B).

At a second measuring period set up at the subjects' convenience during the next two weeks, the subjects were given four cable-tensiometer strength tests to determine static strength: the shoulder extension, the trunk extension, the knee extension, and the ankle plantar flexion. The results of these strength test items were recorded on the subject's score sheet. The shuttle run, as described by Fleishman, was given to determine explosive strength. This was recorded in seconds.

Population

The population of this study consisted of sixty male physical education majors and minors at the University of Alabama in the spring semester of 1969. From an alphabitized list of 208 majors and minors, a random table of numbers was used to select the participants in this study.

Experimentation Schedule

The subjects were given a specified time to report to the research laboratory to be measured in the cylindrical human body volumeter. To guard against a variable caused by excessive food stuffs and water in the intestinal tract, the subjects refrained from eating breakfast and/or drinking an excess of liquids until after their measuring session. The measuring periods were scheduled between six-thirty A.M. and eight A.M. Monday through Saturday.

The Physical Characteristics of the Cylindrical Human Body Volumeter

When it was decided to undertake a study to determine the relationship of lean body mass to strength, it was the intention to construct a human body volumeter as designed by Allen, Krzywicki, Worth, and Nims at the Fitzsimons General Hospital in Denver, Colorado, in 1960.[1] After checking into construction costs in the Tuscaloosa area, it was found that the cost of constructing the rectangular model would be excessively expensive. As a result of this,

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[1]Allen, Human Body Volumeter, pp. 1-5.

the idea was formulated to develop a cylindrical human body volumeter that would be more practical to construct and use. The various advantages of this volumeter are elaborated on page 60.

The body of the volumeter, a cylindrical steel tank, was constructed from three-quarter inch carbon steel, measuring six feet in height, and with a diameter of twenty-eight inches. (See Figure 1, Appendix A). The tank was elevated from the floor by four round aluminum stands which allowed a two inch drain pipe to protrude from the bottom of the tank. This drain pipe has a two inch gate valve that allows the water to be drained in two to three minutes in case of an emergency. (See Figure 2, Appendix A).

A nylon rope, three sixteenths of an inch in diameter, with a testing strength of 740 pounds, was used to lower or raise a steel platform in the tank. The nylon rope was run from a hand powered winch (see Figure 5, Appendix A) over pulleys and through short sections of one-half inch pipe welded to the four corners of the platform; it was crossed diagonally underneath the platform, and then the free end of the rope was attached to a metal eye at the top of the tank. This platform formed an elevator that insured easy entry into and exit from the tank. (See Figure 3 and 4, Appendix A).

A brass needle valve was screwed into the side of the tank to which was attached a two inch piece of copper tubing. A short length of tygon tubing was connected to a glass tube with a three millimeter inner diameter. The glass tube was placed beside a metal scale graduated in millimeters that was held in place by two metal clamps. (See Figure 5 and 6, Appendix A).

The tank was painted with epoxy paint, the type of paint perscribed especially for underwater use. This eliminated the problem of corrosion and also gave the instrument a pleasing appearance.

The estimated weight of the cylindrical human body volumeter, including the various attachments, was 300 pounds.

The Critical Features of the Cylindrical Human Body Volumeter

The cylindrical shape was chosen for simplicity of construction and design. By using a cylindrical steel tank rather than a rectangular plywood, box-type design, the whole process of fiberglassing to make the body of the volumeter water tight was eliminated. The simplicity of construction thus afforded is evident since only one shell provided both the exterior and interior and the need for extra materials and labor was greatly reduced.

A five by eighteen inch window of one-quarter inch plexiglass was built into the side of the tank to allow observation of the subject as he submerged himself in the volumeter. This window served several purposes. It allowed the researcher to observe that the proper procedure was being followed; it provided an added safety feature since the subject was watched at all times; and it reassured the subject by preventing a feeling of claustrophobia while he was being tested. (See Figure 1, Appendix A).

The cylindrical tank was designed with the smallest possible diameter to allow easy entry of larger men weighing up to 120 kilograms. At the same time, it had to provide sufficient water displacement per unit mass submerged to allow reading of the glass tube without mechanical amplification. A diameter of twenty-eight inches provided enough space for a subject to flex his knees and crouch during submersion while still maintaining most of his body in the upper calibrated portion of the tank.

The non-compressibility of water allowed for configurational changes, and the elevator and two hand holds in the lower portion of the tank did not affect the accuracy of the calibrated tube.

Procedure Before Entering the Volumeter

The group of subjects were given a verbal description of the volumeter and any questions they might have about it were answered. They then went through the following procedure.

(1) The subject undressed and took a shower.

(2) The subject reported in the nude to a designated area where two skinfold measures were taken, one on the dorsum of the right arm and one on the right scapula. These were recorded.

(3) The subject then moved to a scale where his weight was measured and recorded to the nearest kilogram.

(4) The subject was then measured and his standing height was recorded to the nearest centimeter.

(5) The subject's age was recorded.

(6) The residual lung volume was estimated from the recorded measures of the subject's age, body weight,

and the mean thickness of the two skinfolds.

(7) The subject was then ready to enter the human body volumeter.

Operation of the Cylindrical Human Body Volumeter

The tank was filled to a scale reading of approximately twenty centimeters with water at 30 $\pm$ 1^{o}C., a comfortable temperature which will not evoke sweating.[2] The researcher then drained approximately two kilograms of water to the nearest gram.[3] He read the null point to the nearest .01 centimeter.[4] The nude subject then climbed to the top of a platform located beside the tank. He lowered himself into the water in the tank until he was standing on the elevator inside the tank. The elevator was then lowered by means of the hand-powered winch until the subject was standing in water up to his neck. The subject was requested to exhale fully, then, while holding his breath, to submerge himself by crouching. The hand holds

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[2]Green, "Lean Body Mass," p. 12.

[3]Allen, Human Body Volumeter, p. 4.

[4]Green, "Lean Body Mass," p. 12.

in the lower portion of the tank enabled the subject to maintain this position easily. While the subject was in this position, the meniscus in the glass tube was read and the researcher immediately tapped on the side of the tank to signal the subject that he could emerge and commerce breathing. The experimenter used urgent commands to insure that the subject had forcefully, completely emptied out his vital capacity. This process was repeated several times until the researcher was sure that he had an accurate reading. Then, with the aid of the hand operated elevator, the subject was raised to a position where he could climb from the tank.

Estimates of Body Fat

From previous studies of the densities of four major components of the body, the quantity of fat can be related to total tissue volume and body weight in healthy persons having normal levels of hydration. The equation can be written

$$F = 4.834\ V - 4.366\ M$$

where the variables are tissue volume, V, determined by total body volume minus residual volume, and body weight, M.[5]

Residual volume was determined using Chinn and Allen's formula

$$V_r = 0.0158\ M + 0.0239\ \bar{S} + 0.00048\ A - 0.261$$

where the variables are body weight, M, the mean thickness of two skinfolds, on the dorsum of the right arm and on the back near the tip of the right scapula, $\bar{S}$, and the chronological age of the nearest birthday, A. This formula by Chinn and Allen has a multiple correlation coefficient of R = 0.963 with measured residual lung volume.[6]

Determining Lean Body Mass

The equation for estimating lean body mass is

$$LBM = M - F$$

where M is the total body weight and F is the estimated amount of body fat.[7]

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[5] Surks, "Exposure to High Altitudes," pp. 1741-1746.

[6] Allen, Human Body Volumeter, p. 22.

[7] Green, "Lean Body Mass," p. 13.

Calibration of the Cylindrical Human Body Volumeter

The tank was filled with tap water at approximately 30^{o} C.±1. This was drained in approximately two kilogram portions weighed to the nearest gram while at the same time the scale reading of the water level in the glass tube was read. The mean calibration constant was 3.862 liters per centimeter of change in water level. For a total of fifty determinations the error of a single standard deviation amounts to .075 liters per centimeter.

Measurement of Strength

The aircraft tensiometer was the instrument used to measure static strength. The tension of the cable was determined by measuring the force applied to a riser causing an offset in a cable stretched between two sectors. This tension was converted to pounds.

Clarke found in comparing the cable tensiometer with other instruments for measuring strength that it has greater precision for strength testing. Also, it is more stable and reliable in its measurement than are the other instruments. Validity on this test was checked under laboratory conditions and the objectivity coefficients were 0.90.[8]

General Testing Instructions

(1) For each cable-tensiometer test, the subject had a specified position.

(2) The known joint angles specified for measuring each test item were made from one inch masonite.

(3) For each test, the tester adjusted the joint in such a way that the angle was correct at the height of pull.

(4) The cable was taunt at the start of each pull.[9]

Description of the Cable-Tensiometer Stength Tests

The cable-tensiometer test battery, as described by Clarke, that was used to measure static strength is described below. The test was administered as follows.

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[8] Harrison H. Clarke, "Comparison of Instruments for Recording Muscle Strength," Research Quarterly, XXV (December, 1954), 398-411.

[9] Green, "Lean Body Mass," p.16.

(1) Trunk extension

<u>Starting position</u> - Subject in prone position; hips 180-degree extension and adduction; knees fully extended; hands clasped behind back.

<u>Attachments</u> - Trunk strap around chest close under arm pits; pulling assembly attached beneath subject through slit in table.

<u>Precautions</u> - Subjects legs must be held down.

<u>Movement</u> - Upon command, the subject attempts to raise his chest from the table.

(2) Knee extension

<u>Starting position</u> - Subject in sitting position, leaning backward; arms extended to rear, hands grasping sides of table; left knee (test side) in 115-degree extension.

<u>Attachments</u> - Regulation strap around leg midway between knee and ankle joints: pulling assembly attached to hook at lower end of table.

<u>Precautions</u> - Prevent lifting buttocks; prevent flexion of elbows.

<u>Movement</u> - Upon command, the subject attempts to straighten the leg.

(3) Shoulder extention

Starting position - Subject in supine position, hips and knees flexed, feet resting comfortably on table; left elbow (test side) pointing toward the ceiling forming an angle of 90-degrees between the humerus and the table.

Attachments - Regulation strap around humerus midway between shoulder and elbow joints; pulling assembly attached to wall beyond subject's head.

Precautions - Prevent shoulder elevation by bracing with hand; prevent humerus abduction by guiding elbow. Prevent left hand from touching cable.

Movement - Upon command, the subject attempts to extend his humerus.

(4) Ankle plantar flexion

Starting position - Subject in supine position, hips in 180-degree extension and adduction, knees in 180-degree extension, arms folded on chest; left ankle (test side) in 90-degree flexion mid-position of inversion and eversion.

Attachments - Regulation strap around foot above metatarsal-phanlangeal joint; pulling assembly attached to wall at subject's head.

Precautions - Prevent inversion or eversion at ankle joint, and raising leg; provide a brace behind subject's shoulders.

Movement - Upon command, the subject attempts to extend the foot.[10]

Description of the Shuttle Run

The shuttle run, as described by Fleishman, was administered to measure explosive strength. Two parallel lines twenty yards apart were marked off on a hard surface. One observer was stationed at the starting line and another at the finish line. Two stop watches were used to time each subject, and the time was recorded to the nearest tenth of a second. At the command "Go" the subject ran to the opposite line twenty yards away and then returned

[10] Clarke and Schopf, "Construction of a Muscular Strength Test," pp. 515-522.

to the starting line until he had run one hundred yards. He was instructed to touch the line on each lap.[11]

Statistical Design

Multiple regression procedures[12] were used in this study. Static strength was the criterion variable and lean body mass, age, height, weight, shuttle run, and percentage of lean body mass were the predictors of the criterion.

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[11] Fleishman, Structure and Measurement, pp. 163-164.

[12] Van Dalen and Meyer, Understanding Educational Research, pp. 365-368.

CHAPTER IV

INTERPRETATION AND ANALYSIS OF THE DATA

As previously mentioned, the purpose of this study was twofold: (1) to develop an experimental instrument that operates on the basis of water displacement to determine lean body mass, and (2) to determine the relationship of lean body mass to static strength as measured by the cable tensiometer. Data for the study were gathered for the following variables--age, height, weight, lean body mass, shuttle run, and percentage of lean body mass. These served as independent variables, and strength was selected as the criterion or dependent variable. With the knowledge of one, or all, or in combination, how well can these variables predict the criterion?

The statistical data were gathered during the spring semester of 1969 at the University of Alabama. Of the original sample of sixty subjects, fifty-four completed the testing. Two of the subjects left school, two were injured and could not take the strength tests, one subject would not submerge himself under water, and one subject could not get a consistent reading on the Id glass and was dropped from the study. The raw data was punched on IBM cards and processed with the use of a Computer 360 Model 50, stored on a BMD03R program located at the Computer Center on the campus of the University of Alabama. The multiple regression equation was used to determine how well the independent variables could predict the criterion.

The .01 level of confidence was selected for the acceptance or rejection of the null hypothesis. Correlations are shown in the tables indicating which variables are significant and how well they predict the criterion.

Correlation Between the Selected Variables and the Criterion

The study attempted to answer the question of how well static strength could be predicted with knowledge of age, height, weight, lean body mass, shuttle run, and percentage of lean body mass.

Table 1 illustrates the relationship of the criterion (static strength) with the selected variables. This correlation matrix was derived from the data gathered in the study. The following relationships were established:

The two weight measures, lean body mass and weight were expected to be highly related due to their physiological relationship. Table 1 shows there is a high correlation (r = 0.8648) between lean body mass and weight; this was the highest in the study.

Table 1 indicates that age has a slight relationship with the shuttle run (r = 0.4270) but the other variables show a negative relationship. The correlation as shown in Table 1 indicates that a poor relationship exists between age and strength (r = 0.0057). This relationship to the criterion was the lowest in the study. This could be explained in part because the mean age of the subjects was 21.6 with a standard deviation of 1.6 years.

Table 1 shows a small relationship between the shuttle run and weight (r = 0.4270), standing height and weight (r = 0.4300), and lean body mass and height (r = 0.4720). The assumption that a person's weight

TABLE 1

CORRELATION MATRIX FOR VARIABLES INVOLVED IN THIS STUDY

Measures	Age	Height	Weight	Lean Body Mass	Shuttle Run	Percent of Lean Body Mass	Strength
Age	1.0000	-.0486	0.1796	0.1354	0.4270	-0.0472	0.0057
Height		1.0000	0.4303	0.4720	-0.0560	0.0905	0.3678
Weight			1.0000	0.8648	0.4507	-0.1477	0.5013
Lean Body Mass				1.0000	0.1765	0.3653	0.6191
Shuttle Run					1.0000	-0.4532	-0.1099
Percent of Lean Body Mass						1.0000	0.2862
Strength							1.0000

would increase as he increases in size is verified by these correlations. Table 1 also shows that lean body mass has a moderate correlation (r = 0.3653) with percentage of lean body mass.

In Table 1 it can be noted that a fair relationship exists between percentage of lean body mass and the shuttle run (r = 0.4532). Since a high score on the shuttle run, a timed test item, indicates a poor performance, this minus relationship can be considered as fair. However, this negative relationship did not show up between the shuttle run and lean body mass (r = 0.1765). This is not consistent with the idea that success in the shuttle run should be highly related to lean body mass.[1] The relationship with the other independent variables as shown in the matrix is negligible. Therefore, it would be ineffectual to compare these to the criterion.

The relationship between height and strength has a slight correlation (r = 0.3678) as shown in Table 1. The two weight measures, total body weight and lean body mass, in combination with height, have the highest correlation

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[1]Fleishman, Structure and Measurement, p. 96.

of combined variables with the criterion, total static strength. Lean body mass and total body strength have a correlation of r = 0.6191, weight to strength, r = 0.5013, and height to strength, r = 0.3677. Of the predictors studied, lean body mass and total body weight are the only ones that are statistically significant predictors of strength. Therefore, in predicting a subject's total static strength, lean body mass and total body weight are better than chance.

Table 2 contains the mean, standard deviation, and range gathered from the data. The mean weight of body fat was 11.65 kilograms. This statistic was lower than the mean that Green found in using a similar technique; he found a mean body fat of 19.58 kilograms which was much higher than the one found in this study.[2] However, the range of body fat in this study was smaller when compared with Green and Krzywicki's findings. The body fat measures in this study ranged from 5.07 to 25.94 kilograms. Green reported a range of 7.81 to 33.80 kilograms.[3] Krzywicki

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[2] Green, "Lean Body Mass," p. 25.

[3] *Ibid.*, p. 24.

TABLE 2

PREDICTION TABLE: MEAN, STANDARD DEVIATION AND RANGE

Predictors	Mean	Standard Deviation	Range Low	Range High
Age (month)	21.3	1.6	18.6	26 2
Height (centimeters)	180.08	6.62	158.5	194.7
Weight (kilograms)	79.42	10.03	58.06	99.62
Lean body mass	67.71	9.13	50.57	84.29
Percentage LBM	85.35	5.70	67	92.7
Strength (pounds)	846.85	147.37	492.	1260.
Shuttle run (seconds)	19.4	.6	21.8	18.2
Fat (kilograms)	11.65	3.89	5.07	25.94

reported a range of 5.85 to 37.96 kilograms when measuring military personnel in different age brackets.[4] These ranges seemed comparable to this study when analyzed in

[4] Allen and others, Human Body Volumeter, p. 15.

light of the mean age of the subjects, 21.3 years in this study as compared to 28 years in Green's. As shown in Table 2, the lowest measure of body fat, 5.07 was lower than those recorded by Green[5] and Krzywicki,[6] 5.69 and 5.85 kilograms respectively. The variation between the range and the mean of height and total body weight was about the same as reported by Green. Table 2 shows the mean strength measurement was 846.85 pounds with a standard deviation of 147.36 pounds; this measure was in line with other similar findings.

Multiple regression procedures[7] were used to identify the contributions of each predictor and combination of predictors toward the criterion, total static strength. The combination of the predictors age, height, weight, lean body mass, shuttle run, and percentage of lean body mass made up the full model. Table 3 shows the full model had an $R^2 = 0.4475$. The regression equation

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[5] Green, "Lean Body Mass," p. 24.

[6] Allen and others, Human Body Volumeter, p. 15.

[7] Van Dalen and Meyer, Understanding Educational Research, pp. 365-368.

TABLE 3

SUMMARY TABLE FOR MULTIPLE REGRESSION PROCEDURES: FULL MODEL AND FULL MODEL WITH A PREDICTOR OMITTED

	R*	R^2**
Full model	0.6687	.4475
Full model-age	0.6681	.4475
Full model-lean body mass	0.6671	.4448
Full model-height	0.6661	.4435
Full model-percent of lean body mass	0.6649	.4401
Full model-weight	0.6637	.4395
Full model-shuttle run	0.6323	.3994
Full model-lean body mass and weight	0.4485	.2013

*Multiple regression correlation
**Variance that can be accounted for

explained 45 percent of the statistical variance that could be accounted for in the full model.

The removal of age from the full model slightly lowers the approximation to 44 1/2 percent. The removal of height shows R^2 = 0.4435, or 44 percent of the variance was accounted for. When weight is removed from the full model, the variance is only lowered to 43 percent. R^2 = 0.4448, or 44 1/2 percent of the variance is accounted for when lean body mass was dropped from the full model. However, when total body weight and lean body mass are removed from the full model of predictors, only $R^2 = 0.2013$ or 20 percent of the variance can be accounted for.

The correlation matrix as shown in Table 1 identifies the best predictor or predictors of static strength, and shows their relationship with each other. Table 4 shows how well the variable or combination of variables can predict the criterion. The best single predictors of static strength as shown in Table 4, are lean body mass ($R = 0.6191$), weight ($R = 0.5013$), and height ($R = 0.3678$). Lean body mass in predicting strength can account for ($R^2 = 0.3831$) 38 percent of the variability. Weight is the next best single predictor ($R^2 = 0.2510$) and accounts for 25 percent of the statistical variance. The multiple correlations of age, height, shuttle run, and percentage of lean body mass are negligible as single predictors of static strength.

When weight and shuttle run are added to lean body mass they become the best combination of predictors of the criterion ($R = 0.6632$) or $R^2 = .4395$ of the $R^2 = .4475$ of the variability that is accounted for by the full model as shown in Table 3 and Table 4. When using lean body

TABLE 4

MULTIPLE REGRESSION PROCEDURES: COMBINATION OF PREDICTORS TO CRITERION

	R*	R^2**
Weight, lean body mass, and shuttle run	0.6632	.4395
Lean body mass, percentage of lean body mass, and shuttle run	0.6622	.4382
Lean body mass and shuttle run	0.6580	.4329
Weight and lean body mass	0.6228	.3868
Lean body mass and percentage of lean body mass	0.6225	.3868
Lean body mass	0.6191	.3831
Age, height and weight	0.5325	.2830
Height and weight	0.5288	.2787
Weight	0.5013	.2510
Height and percentage of lean body mass	0.4470	.1998
Age and height	0.3685	.1354
Height	0.3678	.1346
Percentage of lean body mass and shuttle run	0.2871	.0823
Percentage of lean body mass	0.2862	.0817
Shuttle run	0.1099	.001
Age	0.0057	.0003

*Multiple regression correlation
**Variance that can be accounted for

mass, percentage of lean body mass, and the shuttle run as predictors of static strength, this combination accounted for R^2 = .4382 or almost the same variability that the best combination of predictors, lean body mass, weight, and the shuttle run, accounted for.

The best combination of two variables, lean body, mass and the shuttle run, accounted for 43 percent of the variability as shown in Table 4. It was assumed that the best predictors would be lean body mass and total body weight, but they only accounted for R^2 = .3906 or 39 percent of the statistical variance. The above premise was proved true in a similar study by Green,[7] but it did not hold true in this study. The shuttle run (R = 0.1099) was a poor predictor of the criterion when viewed alone, but when matched with lean body mass, it became one of the best predictors of static strength. However, its r = -0.4532 relationship did indicate a fair relationship with percentage of lean body mass as shown in Table 1. Since the higher score indicated poorer performance, a minus relationship showed a positive prediction to the criterion.

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[7]Green, "Lean Body Mass," p. 24.

Table 4 shows that using the standard age, height, and weight measurements for predicting strength is not any better than a guess, R^2 = .2830 or 28 percent of the variability is accounted for. Standing height and total body weight as predictors of strength accounted for only 27 percent of the variability as shown in Table 4. The other combinations were so small as predictors of the criterion that it is not advisable to use them for predicting static strength.

Statistical Application of the F Test

The statistical F tests were used to determine which predictors are needed to insure the ability to predict strength over chance.[8] The F tests and their results are shown in Table 5.

All predictors minus weight and lean body mass was not significant at the .01 level but showed significance at the .05 level. The use of all predictors against chance were significant at the .01 level except percentage of lean

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[8]Janet T. Spence and others, "Elementary Statistics (2nd ed. New York: Appleton-Century-Crafts, 1968), pp. 161-162.

TABLE 5

TABLE FOR THE STATISTICAL F TEST

Test	df	Calculated F	Table F	Level of Significance
All predictors vs. zero	6,53	6.33	3.20	.01
Weight only vs. zero	1,55	17.45	7.55	.01
Lean body mass vs. zero	1,53	32.32	7.15	.01
Weight and LBM vs. zero	2,53	16.16	5.08	.01
All predictors- wt. and LBM vs. zero	4,53	3.08	3.68	.05
All predictors- LBM vs. zero	5,53	7.69	3.39	.01
All predictors- age vs. zero	5,53	7.74	3.39	.01
All predictors- height vs. zero	5,53	7.65	3.39	.01
All predictors- percent LBM vs. zero	5,53	7.60	3.39	.01
All predictors- weight vs. zero	5,53	7.55	3.39	.01

TABLE 5—Continued

Test	df	Calculated F	Table F	Level of Significance
All predictors-shuttle run vs. zero	5,53	6.39	3.39	.01
Height and LBM vs. zero	2,53	16.35	5.08	.01
Lean body mass and shuttle run vs. zero	2,53	19.47	5.08	.01
Height and weight vs. zero	2,53	9.90	5.08	.01
Weight, LBM, and shuttle run vs. zero	3,53	13.09	4.21	.01
Age, height, and weight vs. zero	3,53	6.59	4.22	.01
Lean body mass and percent lean body mass vs. zero	2,53	16.13	5.08	.01
Weight and lean body mass vs. zero	2,53	15.89	5.08	.01
Height and percent lean body mass vs. zero	2,53	6.36	5.08	.01

TABLE 5—Continued

Test	df	Calculated F	Table F	Level of Significance
Percent lean body mass and shuttle run vs. zero	2,53	2.29	5.09	NS
Age and height vs. zero	2,53	4.00	5.08	NS
Age vs. zero	1,53	.001	7.15	NS
Percent lean body mass vs. zero	1,53	4.64	7.15	NS
Shuttle run vs. zero	1,53	.63	7.15	NS

body mass, shuttle run, age and height, and age. One can more accurately predict an individual's strength from knowledge of age, height, weight, lean body mass, shuttle run, and percentage of lean body mass than by use of chance. When testing the single predictor lean body mass or weight against chance, both were significantly better at the .01 level. The same is true when lean body mass and weight were used in combination against chance as shown in Table 5.

Using the full model of predictors against chance and omitting one variable at a time, they are all significant at the .01 level. However, when lean body mass and weight are dropped simultaneously from the full model, the results are not significant against chance at the .01 level but are at the .05 level as indicated in Table 5.

Summary

This chapter has presented the statistical findings of the study pertaining to (1) the relationship of lean body mass to static strength, and (2) how well with knowledge of age, height, weight, lean body mass, shuttle run, and percentage of lean body mass one can predict the criterion.

Data obtained from the BMD03R program were presented and analyzed regarding the correlation and multiple regression analysis aspects of this study. The F tests for significance were used to determine if chance could have predicted the results of this study.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

It was the purpose of this study to (1) determine the relationship of lean body mass to static strength, and (2) see how well static strength can be predicted with knowledge of age, height, weight, lean body mass, shuttle run, and percentage of lean body mass.

This study was conducted by obtaining a random sample of fifty-four male physical education majors and minors from an alphabitized list of two hundred and eight subjects enrolled at the University of Alabama for the year 1969. The subjects were submerged in the cylindrical human body volumeter to determine their lean body mass. Age, height, weight, lean body mass, shuttle run, and the summation of static strength were recorded on a score sheet.

These data were analyzed with the use of a BMD03R program at the University of Alabama Computer Center. An F test was used to determine if results could have been caused by chance.

Null Hypothesis

The following null hypotheses were proposed for testing.

(1) Lean body mass is not related to static strength. (Rejected) Lean body mass is the best single predictor of strength in this study. Green, in a similar study, found lean body mass to be the best single predictor of static strength.[1]

(2) Age does not contribute anything to the prediction of static strength that is not already predicted by height, weight, lean body mass, shuttle run, and percentage of lean body mass. (Accepted) The F value for age is so low that it cannot be considered any better than chance for predicting static strength. Since the age of the subjects was clustered so closely around the mean, this was a reasonable finding.

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[1] Green, "Lean Body Mass," p. 30.

(3) Weight does not contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, height, shuttle run, and percentage of lean body mass. (Rejected) Total body weight was the second best predictor of static strength that was found in this study. The multiple R for this study was higher than the one reported by Green.[2] This is probably due to the fact that the subjects for this study were physical education majors and minors whereas Green's subjects were volunteers of varying ages.

(4) The shuttle run does not contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, height, weight, and percentage of lean body mass. (Accepted) The shuttle run was not significant at the .01 or .05 levels. Fleishman has indicated in his factor analysis studies that the shuttle run is a good predictor of explosive strength,[3] and it was assumed by the researcher that it would have a good relationship with static strength. However, this

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[2] _Ibid_., p. 26.

[3] Fleishman, _Structure and Measurement_, p. 128.

was not found to be true in this study.

(5) Percentage of lean body mass does not contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, height, weight, and the shuttle run. (Accepted) Schifferdecker[4] and Leedy[5] indicated in previous studies with college subjects that percentage of lean body mass was more important in the success of activities than lean body mass. This was not found to be the case in this study. However, when lean body mass and percentage of lean body mass were combined, they became an effective predictor of static strength.

(6) Height does not contribute anything to the prediction of static strength that is not already predicted by lean body mass, age, weight, shuttle run, and percentage of lean body mass. (Rejected) Height, even though it was significant at the .01 level, was a poor predictor of strength, only accounting for 13 percent of

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[4]Schifferdecker, "Whole Body Radioactivity," pp. 269-272.

[5]Leedy, "Performance Items and Composition," p. 162.

variability. This was about the same results that Green found.[6]

When the shuttle run was matched with lean body mass to predict static strength, they became one of the best combinations of predictors in the study ($R = 0.6622$ or 44 percent of the variability).

The mean body fat in this study was found to be lower than was found in other studies. This significant difference could be caused by the nature of the sample, physical education majors and minors.

The removal of any one of the variables from the full model did not significantly affect the prediction of the criterion. However, when both body weight and lean body mass were dropped from the full model, it could not significantly predict the criterion over chance. This was also found to be true in Green's study.[7]

The best combination of predictors for the criterion was weight, lean body mass, and the shuttle run. This combination accounted for approximately 44 percent of the

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[6] Green, "Lean Body Mass," p. 22.

[7] *Ibid.*, p. 26.

45 percent of the variability of the full model.

Using standard height, weight, and age measures for predicting strength are not much better than a guess and their use is not recommended.

Conclusions

The conclusions drawn from this study apply to physical education majors and minors at the University of Alabama during the spring of 1969, within the limitations as stated in Chapter I. Based on the statistical analysis of the data, the conclusions are as follows:

(1) The use of lean body mass, age, height, weight, shuttle run, and percentage of lean body mass are significantly better predictors of total static strength than chance at the .01 level.

(2) The use of lean body mass is a significantly better predictor of total static strength than chance at the .01 level.

(3) The use of total body weight is a significantly better predictor of total static strength than chance at the .01 level.

(4) The use of the shuttle run does not significantly predict static strength at the .01 level.

(5) The use of percentage of lean body mass is not a significantly better predictor of total static strength than chance at the .01 level.

(6) The mean and range of body fat was significantly lower than was found in other studies; this was probably due to the nature of the sample.

(7) The use of the shuttle run and lean body mass to predict total static strength is significantly better than chance at the .01 level.

(8) The omission of lean body mass and body weight from the full model will eliminate the ability to predict static strength at the .01 level.

(9) The use of age, height, and weight will significantly predict static strength over chance at the .01 level.

Recommendations

Physical educators are continually searching for more feasible ways of estimating static strength. The statistical findings in this study indicate that prediction of static strength from either lean body mass or the full model of predictors is significantly better than a prediction by chance. It also found that lean body mass and the shuttle run were better predictors of static strength than chance. However, the use of lean body mass as a predictor accounts for 38 percent of the variability, lean body mass and the shuttle run only 44 percent of the variability, and the full model of predictors only 45 percent of the variability. This percentage is relatively low and could not be recommended for use except when one is looking for an estimation that would be better than chance.

The following areas are suggested for further research.

(1) Studies should be conducted to determine the relationship of lean body mass to subjects skilled in specific activities such as basketball, football, baseball, track and field, swimming, wrestling and weight lifting.

(2) To determine which biophysical method is best for estimating lean body mass, a comparison of the volumeter designed for this study with an underwater weighing method

should be made.

(3) Since the cylindrical human body volumeter is a new instrument, there is a need for comparative studies to establish validity.

(4) There is a lamentable lack of body composition studies regarding women. Few studies, to this writer's knowledge, have been made using biophysical methods. The writer sees this as a need and recommends the use of the human body volumeter for testing female subjects.

(5) Another interesting study could be made comparing non-athletic college students to athletic students. The results concerning percentage of fat and percentage of lean body mass should be interesting and revealing.

(6) Larger samplings of subjects of varying ages should be tested since most of the studies to this date have been made with small samplings and with subjects of approximately the same age.

(7) A comparative study using Negro and white subjects would provide interesting data on race differences.

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APPENDIX A

Figure 1

Figure 2

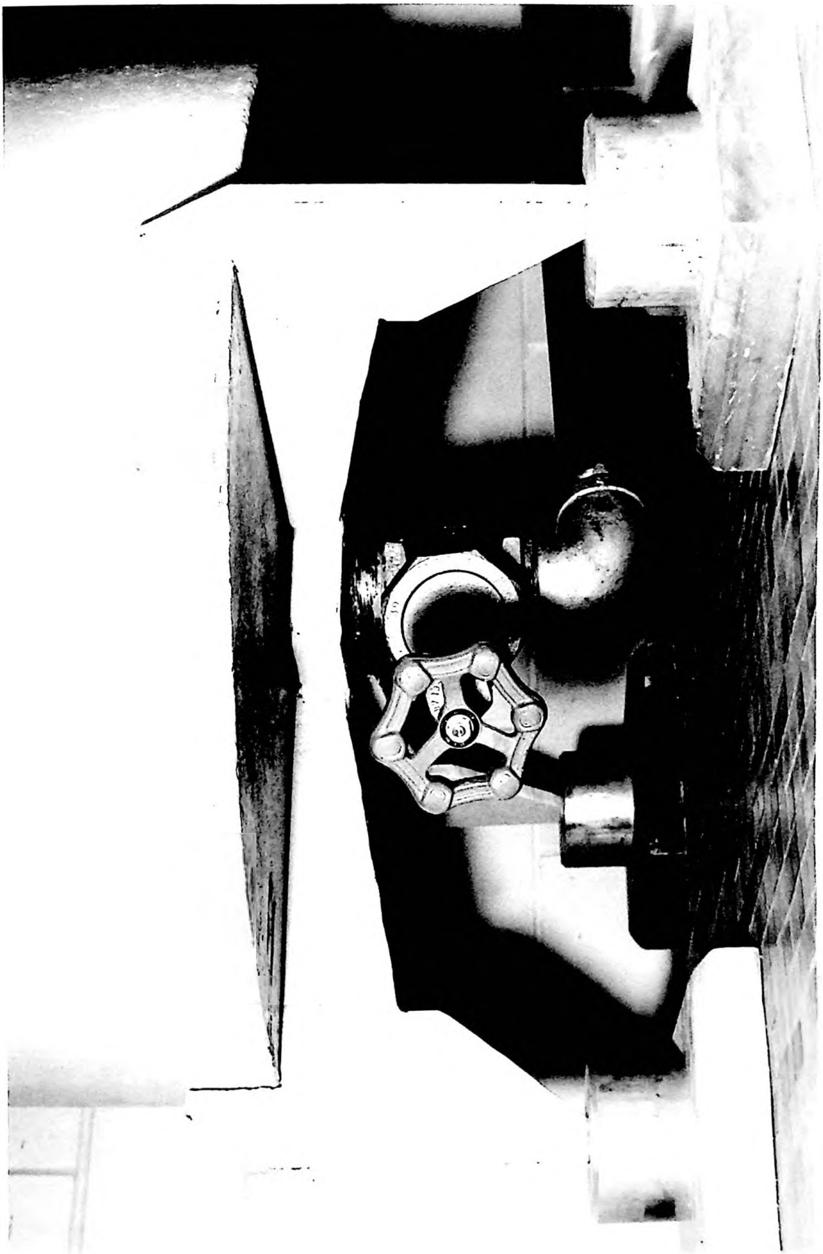

Figure 3

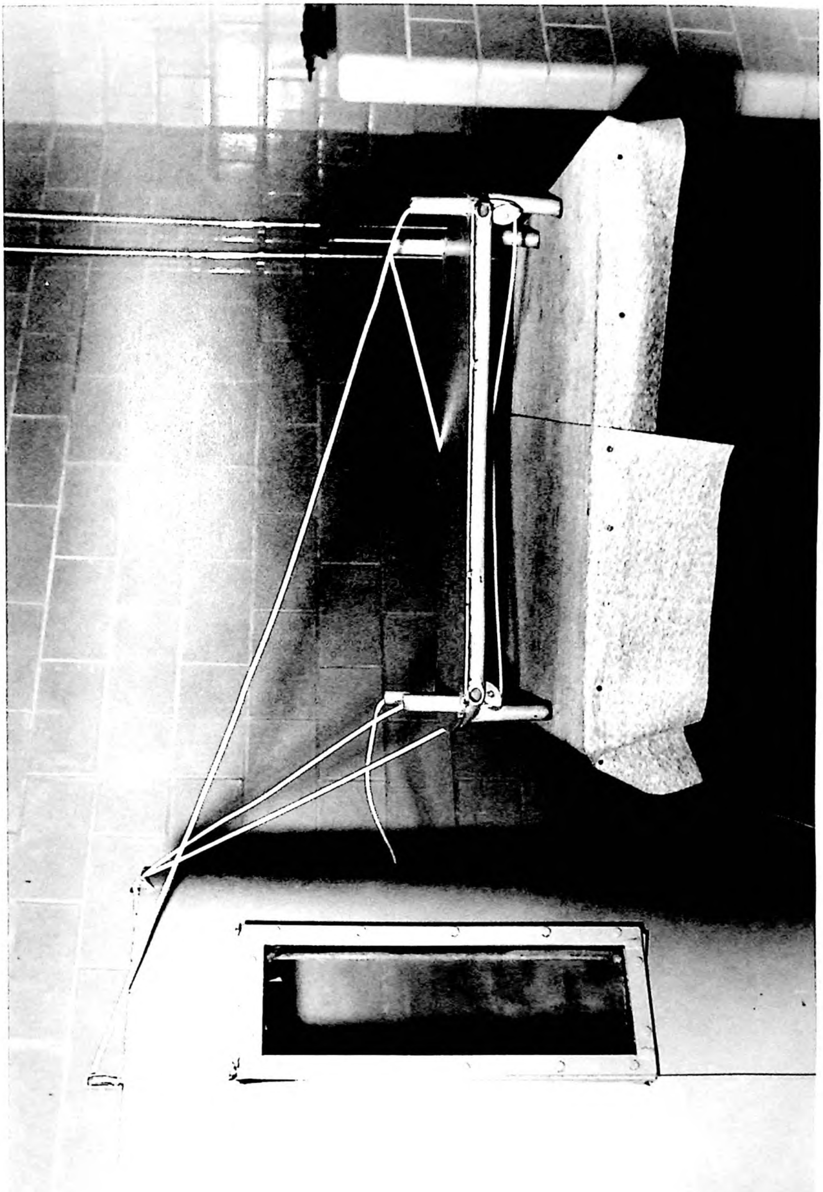

Figure 4

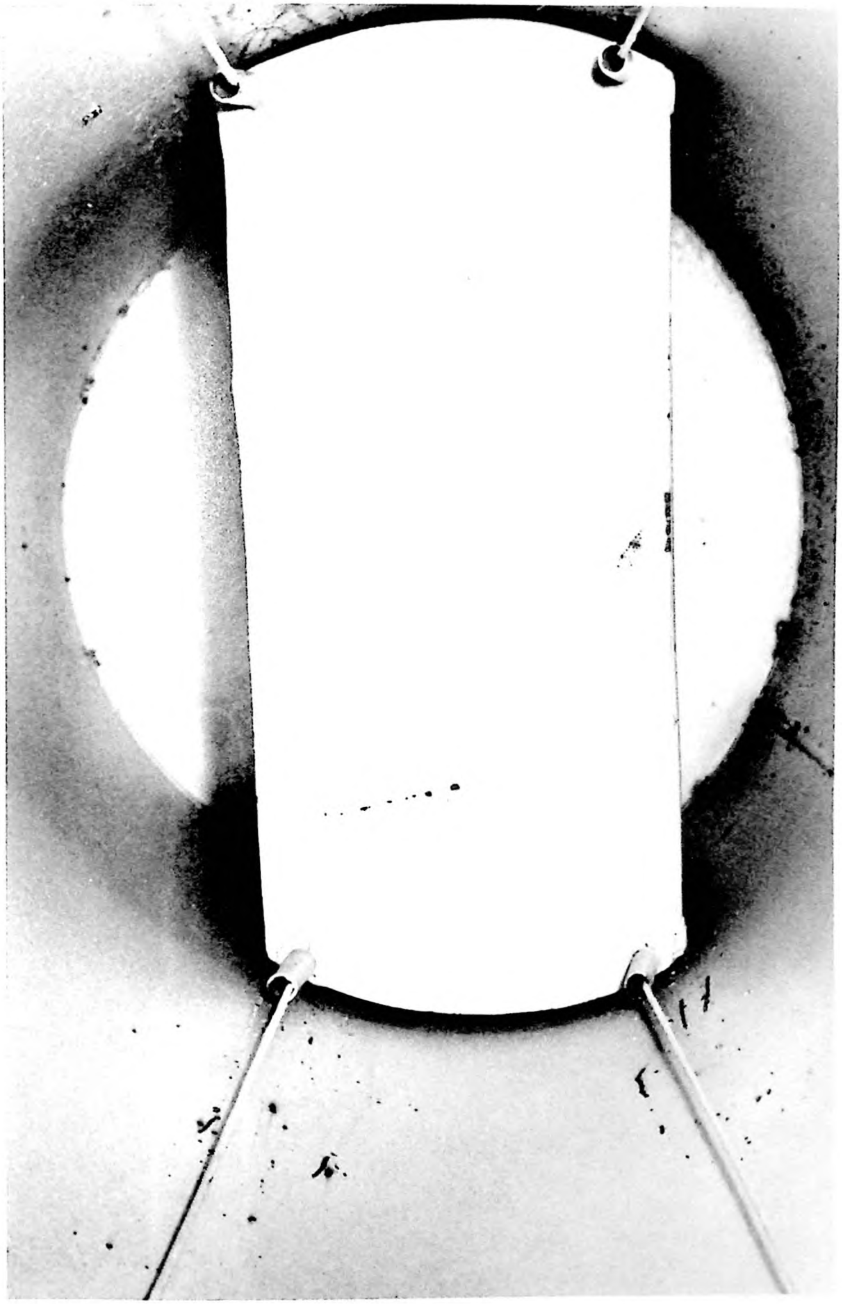

Figure 5

APPENDIX B

April 14, 1969

You are one of sixty students chosen randomly from a list of physical education majors and minors to participate in a set of measurements to determine the amount of your lean body mass. This is accomplished by submerging yourself in a special tank called a human body volumeter. At the same appointment we will also get information concerning your height, weight, etc. This process should not take longer than fifteen or twenty minutes but must be done early in the morning before you have eaten. Your cooperation in meeting your appointment promptly will be greatly appreciated. At a later date you will be asked to come in (at a convenient time set up by you) to take a set of strength tests which will take about an hour. This information will be used in a study being made to determine the relationship of lean body mass to strength. Thank you beforehand for your participation and time.

Sincerely,

Travis E. Clark

TEC:bc

Appointment Slip

Name________________________________
Place of Appointment________________________
Time of Appointment________________________

Please do not eat breakfast (or any other food) or drink an excess of fluids on the morning of your appointment.

SCORE CARD

No.________Name____________________________Age____Sec.____

Height________Weight________ Test Date__________Time______

End____________

Null ______________

Test- Null ______________

Cal. Vol. ______________

Residual V. ______________

% Body Fat __________

Body Fat __________

L B M __________

% L B M __________

CABLE TENSIOMETER Test Date____________Time______

Shoulder Extension	________	____________	Avg. __________
Trunk Extension	________	____________	Avg. __________
Knee Extension	________	____________	Avg. __________
Ankle Plantar Flexion	________	____________	Avg. __________

Total Strength __________

Shuttle Run __________

Skinfold:

Triceps __________

Scapula __________

COMMENTS: