FOUR METHODS OF PREDICTING PER CENT BODY FAT IN MEN AS COMPARED TO UNDERWATER WEIGHINGS

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PREFACE

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CHAPTER I

INTRODUCTION

Obesity is a major health problem in the United States. The general public has very little knowledge concerning the area of obesity. Overweight to most individuals is determined by looking at height-weight charts in a doctor's office. Overweight and obesity are not the same and individuals should be aware of this fact. A person could be overweight according to a height-weight chart and not be obese (excessive amount of fat). The only way to properly determine whether a person is obese is by measuring or predicting a person's per cent body fat. This may be done by several methods, one of which is hydrostatic weighing.

One of the most accurate and widely used methods for assessing body volume, hydrostatic weighing, utilizes Archimedes' basic physical principle. The principle is that a body immersed in a fluid is acted on by a buoyance force. The buoyance force is then evidenced by a loss of weight equal to the weight of the displaced fluid.[1,2]

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[1]A. R. Behnke and Jack H. Wilmore, Evaluation and Regulation of Body Build and Composition (Englewood Cliffs, N. J., 1974), p. 22.

[2]A. Keys and J. Brozek, "Body Fat in Adult Man," Physiol. Rev., 33 (July, 1953), p. 245.

Behnke was the first to make adequate estimates of total body volume using this technique in the late 1930's.[3] From this method the specific gravity is found and used in formulas for determining per cent body fat, such as those equations developed by Rathburn and Pace, Brozek, and Siri.[4,5,6] The Brozek formula was used in this study, as a matter of preference, since the equations result in similar values for calculated relative fat.[7]

Purpose of the Study

The purpose of the study was to determine the validity of four methods of obtaining per cent body fat in men using the results of underwater weighing as the criterion.

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[3] A. R. Behnke, B. G. Feen, and W. C. Welham, "The Specific Gravity of Healthy Men," JAMA, 118 (February, 1942), p. 495.

[4] E. N. Rathburn and N. Pace, "Studies on Body Composition," J. Biol. Chem., 158 (May, 1945), p. 670.

[5] J. Brozek, F. Grande, J. T. Anderson, and A. Keys, "Densiometric Analysis of Body Composition: Revision of Some Quantitative Assumptions," N. Y. Acad. Sci., 110, Part 1 (1963), p. 120.

[6] W. E. Siri, "Gross Composition of the Body," In Advance in Biological and Medical Physics IV, edited by J. H. Lawrence and C. A. Tobias (New York, 1956), p. 113.

[7] Jack H. Wilmore and A. R. Behnke, "Predictability of Lean Body Weight Through Anthropometric Assessment in College Men," J. Appl. Physiol. 25, 4 (1968), p. 349.

Hypothesis

There will not be a high (r = .80 or above) correlation between the four methods being tested and underwater weighing.

Subproblems

1. To compare the per cent body fat found in four age groups: 25-34, 35-44, 45-54, and 55-68.

2. To compare the body fat between groups with different activity patterns.

The per cent body fat was also compared between faculty members and administrators and also between faculty members of different departments.

Delimitations

1. The subjects used were a select, voluntary group of male faculty members and administrators from a small, private, church related, liberal arts college.

2. The four methods of obtaining per cent body fat in men and underwater weighing were the only measurements used to determine the per cent body fat or relative body fat of the subjects tested.

Limitations

1. The subjects for the study were volunteers.

2. Physical activity patterns were based on what the subjects reported.

3. The residual lung volume was estimated.

Assumptions

1. The underwater weighing method is valid.

2. The author has the necessary skill to perform the underwater weighing technique validly and reliably.

Justification

Heart or circulatory diseases are responsible for more than 50 per cent of the deaths in the United States and many developed countries.[8] Obesity/adiposity (body fatness) is one of the factors which influences heart disease and is a factor that can be controlled or altered by the individual. If individuals have a knowledge of what they can do to alter or control their body fat, it could help them in being less likely to have heart disease or disease of the circulatory system.

Many individuals do not know what their per cent body fat is and do not have a means for obtaining this information. If methods other than underwater weighings are accurate means of measuring body fat, there would be less need for the general public to spend their time and money for a physical fitness appraisal at some medical facility,

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[8]Michael L. Pollock, Jack H. Wilmore, and Samuel M. Fox III, Health and Fitness Through Physical Activity (New York, 1978), p. 6.

and they would still have some knowledge of their per cent body fat by using methods capable of being done at home.

Having the individual know what his per cent body fat is at present would be the first step in getting the individual where he should be or maintaining his present level if it is satisfactory.

Selection of Measurements

The methods of predicting per cent body fat in this study were the Sharkey method, Kuntzleman method, Consolazio method, W. R. Best method, and underwater weighings. The Sharkey method was chosen due to its simplicity, and also because it is a recently suggested (1978) method of predicting per cent body fat. Another fairly recent (1975) method of predicting per cent body fat is the Kuntzleman method. This method is still fairly easy to administer and is not very complicated. Two methods that have been popular for some time are the W. R. Best method (1953) and the Consolazio method (1963). Since these methods involve skinfold measurements and the use of nomograms, the difficulty and time involved are greater than the two previously mentioned methods.

According to DeVries, the underwater weighing method pioneered by A. R. Behnke is the most precise method for evaluation of body composition (body fat).[9] Because of the

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[9]Herbert A. DeVries, Laboratory Experiments in Physiology of Exercise (Dubuque, Iowa, 1971).

general acceptance and the wide use of underwater weighing, this method was selected to be used as the criterion.

Sharkey Method

This method is based on the man's body weight and waist girth. From these two figures, the subject's per cent body fat can be predicted by the chart originated by Dr. Brian J. Sharkey, University of Montana, Missoula, Montana.

Kuntzleman Method

Skinfold calipers are used to obtain skinfold thicknesses at four places: the arm (tricep), the arm (bicep), the abdomen, and the back (subscapular). The total of the four measurements are then used in a chart to arrive at the per cent body fat of the subject.

W. R. Best Method

The W. R. Best method involves using skinfold measurements at three places: the arm (tricep), the abdomen, and the chest. From these measurements a nomogram is used to figure the specific gravity and per cent body fat in men.

Consolazio Method

The Consolazio method involves using the age, height, and observed body weight to find the relative body weight per cent of the subject. By using the relative body weight in per cent and the chest, back, and arm (tricep) skinfold measurements, the specific gravity and per cent body fat is obtained by using a nomogram.

Underwater Weighings

The subjects are weighed out of the water, and then ten readings are made while the subjects are in the water. The highest and/or heaviest reading obtained at least two times, with the subject under water and air expired, is used to subtract from the constant weight of the seat and harness to obtain the underwater weight. With the net weight in water plus the weight in air, a formula is used to obtain the specific gravity and per cent body fat of the subject.

Definition of Terms

Skinfold Fat Measures

Chest: diagonal fold one-half of the distance between the anterior-axillary line and nipple.

Abdominal: vertical fold adjacent to and approximately two inches laterally from the umbilicus.

Arm (tricep): vertical fold on the posterior midline of the upper arm (over tricep), halfway between the acromion and olecranon process with the elbow extended and relaxed.

Subscapular (back): fold taken on a diagonal line coming from the vertebral border one inch from the inferior angle of the scapula.

Arm (bicep): vertical fold on the anterior midline of the upper arm (over bicep), halfway between the acromion and olecranon process with the elbow extended and relaxed.

Girth or Circumference Measurements

Shoulder: taken in the horizontal plane at the maximum circumference of the shoulders at the level of the greatest lateral protrusion of the deltoid muscles.

Chest: taken in the horizontal plane at the maximum circumference.

Abdominal: taken in a horizontal plane at the smallest circumference in the abdominal region, generally two to four inches above the umbilicus.

Waist: taken in the horizontal plane at the level of the umbilicus.

Gluteal (buttocks): taken in the horizontal plane at the largest circumference around the buttocks. Subjects stand with feet together and gluteals tensed.

Thigh: taken in the horizontal plane just below the gluteal fold or maximal thigh girth.

Calf: taken in the horizontal plane at the maximum girth of the calf with the muscle tensed.

Ankle: taken in the horizontal plane at the smallest point above the malleoli.

Arm (bicep): taken at the maximal girth of the midarm when flexed to the greatest angle with the underlying muscles fully contracted.

Forearm: taken at the largest circumference with the forearm parallel to the floor, the elbow joint at a 90-degree angle, the hand in the supinated position, and the muscle flexed.

Wrist: taken over the styloid process of the radius and ulna with the arm extended in front of the body and fist clenched, relaxed, and pronated.[10]

Knee: taken in the horizontal plane over the patella.

Other Definitions

Obesity: excessive accumulation of body fat.

Overweight: weight in excess of normal range (which may not involve obesity at all).[11]

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[10]Michael L. Pollock, Jack H. Wilmore, and Samuel M. Fox III, p. 92.

[11]Jean Mayer, Overweight: Causes, Cost, and Control (Englewood Cliffs, N. J., 1968).

CHAPTER II

REVIEW OF SELECTED LITERATURE

Insurance studies have clearly established the correlation between obesity (overweight) and increased mortality from a number of degenerative diseases.[1] However, these studies were based on insurance statistics established in terms of body weight rather than per cent body fat. This has led to a general belief that "overweight" also means "over-fat." Due to this misconception, a person weighing as much as 15 per cent more than the standard weight for his age and height according to weight charts is usually told to reduce.[2] Only in recent years has the complexity of the subject of body weight been fully realized.

Studies dealing with the deposition of fat help one comprehend "normal" body weight and the significance of weight changes. It is not how heavy a man is or how heavy he becomes that is most significant. Rather, it is how much

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[1] Jean Mayer, "Obesity: Diagnosis," Postgrad. Med., 25, (April, 1959), p. 469.

[2] J. Brozek and A. Keys, "Relative Body Weight, Age, and Fatness," Geriatrics, 8 (February, 1953), p. 70.

fat he carries and how much fat he adds.[3] If the real problem is obesity (excess fatness) rather than mere overweight, overweight and fatness must be dissociated to be understood properly.[4]

Body components may be regarded as fat, water, protein, and minerals.[5] The weight of an individual can thus be expressed as weight of fat, water, protein, and minerals, with each expressed as a ratio of body weight. Direct analysis of the gross body composition shows that the greatest variable in the body is fat. In abnormal conditions (e.g., ascites) and in athletes who develop large muscles, excess body water, or muscle mass may contribute substantially to total body weight. In "normal" adult individuals of given height, adipose tissue accounts largely for individual differences in body weight.[6]

In their work on the relationship between body weight and fat in both young and middle-aged men, Brozek and Keys showed that, although a definite average relationship exists between weight and fatness, it is not possible to make a

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[3] S. M. Garn and R. V. Harper, "Fat Accumulation and Weight Gain in the Adult Male," Human Biol., 27 (February, 1955), p. 39.

[4] A. B. Kurlander, S. Abraham, and J. W. Rion, "Obesity and Disease," Human Biology, 28 (May, 1956), p. 203.

[5] J. M. Tanner, "The Measurement of Body Fat in Man," Proc. Nutrition Soc., 18 (March 7, 1959), p. 148.

[6] A. Keys and J. Brozek, "Body Fat in Adult Man," Physiol. Rev., 33 (July, 1953), p. 245.

reliable prediction of fatness from body height and weight.[7] In one study, body composition was measured in 38 young men and all of them were overweight by standard height-weight tables. Although all of the subjects were overweight, only six were obese.[8]

A closer look at the data revealed even more disturbing limitations to body weight as a measure of fatness. Men of the same relative weight, but of different ages, differed greatly in fatness. For young men whose weights were within plus or minus five per cent of the standard weight, body fat was found to be less than half as much as in middle-aged men who were also within plus or minus five per cent of the standard weight. By standard weight tables, the two groups would be considered equivalent.[9]

In a study of 403 females and 356 males of the Czechoslovakian population using hydrostatic weighing, fat values were found to increase with age. In both sexes, the highest difference in the percentage of fat was observed between the second and third decennium. Body weight was also found to increase with age up to 40 years of age. On the other hand, from 40 through 49 years a decrease in

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[7] J. Brozek and A. Keys, "The Evaluation of Leanness-Fatness in Man: Norms and Interrelationships," Brit. J. Nutrition, 5 (1951), p. 194.

[8] D. A. Clark, T. D. Kay, R. F. Tatsch, and C. F. Theis, "Estimations of Body Composition by Various Methods," Aviat. Space Environ. Med., 48, 8 (August, 1977), p. 702.

[9] J. Brozek, and A. Keys, Geriatrics, 8, p. 70.

weight was found both in male and female means, with the body heights also less in older subjects.[10]

Welham and Behnke showed in their study of professional football players that "overweight" could not be simply equated with "obesity." The athletes were actually "thin" on the basis of a low body fat content, although their average body weight was 24.6 per cent above the army standard for men of the same height and age.[11]

Brozek and Keys, in their study of two groups of individuals within a more normal range of physical activity, also found that physically active men were overweight, yet somewhat underfat. All subjects were free of clinical abnormalities, matched in age and height, and were engaged in executive and/or clerical work. The only difference was the extent of their physical activity and exercise. Individuals in the "inactive" group had always been relatively sedentary while the "active" group maintained the habit of regular exercise. The active men were heavier, thus relatively "overweight"; however, their specific gravity was higher, and their fat content was lower. They were leaner

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[10]R. Petrasek, K. Hajinis, J. Loubova, J. Misikova, and R. Rath, "Relation to Body Fat to Age in the Caech Population," Am. J. Phys. Anthropol., 51, 1 (July, 1979), p. 132.

[11]W. C. Welham and A. R. Behnke, "Specific Gravity of Healthy Men; Body Weight + Volume and Other Physical Characteristics of Exceptional Athletes and Naval Personnel," JAMA, 118 (February 14, 1942), p. 498.

than the inactive men, their lean body mass being considerably larger than in the inactive group.[12]

Overweight and lack of exercise are often related. Those who are overweight tend to exercise less, and lack of exercise tends to add weight. Losing weight depends on the balance between calories expended by activity and calories acquired by ingestion. Other factors (glandular) are rarely important. As physical energy is expended, weight loss will occur. If caloric intake is reduced while additional calories are burning, weight loss is assured.[13,14] In relation to this, data obtained from 77 adult Micronesian (Nauruan) subjects during a diabetes epidemiological survey showed that obesity was a pronounced feature of this population and the high caloric intake coupled with reduced physical activity would appear to be a major factor in relation to obesity.[15]

The general age trend of fat in man is well known. The peaks of fatness are in early childhood and in late maturity. The thickness of subcutaneous fat shows a rise in infancy, a decrement in childhood, and another rise in adolescence.

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[12] J. Brozek and A. Keys, Geriatrics, 8, p. 70.

[13] Fred W. Kasch and John L. Boyer, Adult Fitness Principles and Practice (Palo Alto, Ca., 1968), p. 123.

[14] William J. Bowerman and W. E. Harris, Jogging (New York, 1967).

[15] H. Ringrose and P. Zimmet, "Nutrient Intakes in an Urbanized Micronesian Population With a High Diabetes Prevalence," Am. J. Clin. Nutr., 32, 6 (June, 1979), p. 1335.

The tendency toward increased fat deposition with age and changes in the distribution of subcutaneous fat are also well known.[16,17] Maturity is reached by the third decade of life, when vertical growth stops. However, termination of skeletal growth, and an abrupt end to increments in "operational" tissue, often mark the beginning of fat accumulation and progressive changes in the surface contours of the body.[18]

While adult fat gain may be partly due to developmental factors, current opinion stresses the nutritional aspect. The problem is not simply one of increased caloric intake, since fat storage may also be accelerated by a decrease in energy expenditure. The appetite in the adolescent and in the young adult may be due to physiological factors; but, as appetite becomes more a habit than an expression of need, and as voluntary activity declines, the excess of caloric intake over caloric expenditure leads to fat accumulation. Voluntary activity may decline during the third and fourth decades, leveling off thereafter.[19] This relation between physical activity and appetite is too often misunderstood and minimized, and it is probably the basis for the slow

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[16]J. Brozek, "Physique and Nutritional Status of Adult Men," Human Biology, 28 (May, 1956), p. 124.

[17]A. Keys and J. Brozek, p. 250.

[18]S. M. Garn and R. V. Harper, "Fat Accumulation and Weight Gain in the Adult Male," Human Biology, 27 (February, 1955), p. 39.

[19]Ibid.

accumulation of excess fat in many sedentary middle-aged persons who show no particular defect in the physiologic mechanism regulating food intake.[20] The concept of "normal" body weight, as defined actuarially, tends to obscure the profound changes that occur in the process of aging. Aging involves not only additive accumulation of body fat but, very likely, some replacement of muscle (and other "active tissues") by fat.[21]

There is evidence that during each decade after age 25 the body loses about three per cent of its metabolically active cells. If this loss of tissue is replaced, it is probably replaced by fat tissue, so that even if an individual maintains constant weight as he grows older, he probably carries an increasing proportion of fat tissue.[22]

Obesity is a national health problem in the United States. The concern of the general population and health professionals is the association of excess body fat with increasing incidence of disease and mortality. Studies have shown that obese adults are more susceptible than are those of normal weight to arthritis, cancer, cardiovascular disease, diabetes, gall bladder distrubances, hernia, certain forms of liver disease, and other health impairments.

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[20]Mayer, p. 469.

[21]J. Brozek and A. Keys, "Limitations of the 'Normal' Body Weight as a Criterion of Normality," Science, 112 (December 29, 1950), p. 788.

[22]Herbert A. DeVries, Physiology of Exercise, (Dubuque, Iowa, 1974), p. 252.

Overweight individuals also had twice as many new cases of arteriosclerotic heart disease as those weighing less than average; and, as the degree of obesity increased, arteriosclerotic heart disease risk increased in both men and women.[23,24,25] In relation to this, Mann found that increased food intake in men did not cause obesity or high blood lipid levels if the excess caloric intake was expended in the form of exercise.[26]

Insufficient knowledge and/or lack of motivation in regard to weight control might be reasons for the prevalence of obesity. The increased mechanization of our society, resulting in decreased activity and increased leisure time for many people has some relation to the problem, also. Jean Mayer, M.D., stated that; inactivity is the most important reason behind the problem of overweight in modern Western societies. The regulation of food intake was never designed for the highly mechanized sedentary life without getting fat, the individual will have to step up his activity

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[23] Philip E. Allsen, Joyce M. Harrison, and Barbara Vance, Fitness for Life (Dubuque, Iowa, 1976), p. 45.

[24] Commission on Chronic Illness, Chronic Illness in the United States; Vol. I, Prevention of Chronic Illness (Cambridge, Mass., 1957), p. 227.

[25] Perry B. Johnston, Wynn F. Updyke, Donald C. Stolberg, and Maryellen Schaefer, Physical Education A Problem Solving Approach to Health and Fitness (New York, 1966), p. 49.

[26] G. V. Mann, "Exercise in the Disposition of Dietary Calories," New England J. Med., 253 (1955), p. 349.

or be hungry all his life.[27] His studies also indicated that fat children often eat less and are much less active than children of normal weight. The same conclusions have been derived from controlled animal studies.[28]

Two fallacies concerning diet and exercise often mislead the public. One is that exercise always increases the appetite, and therefore, results in no weight loss. The other is that exercise expends only a small number of calories, and hence, only an exhaustive program can be beneficial.

The facts are that an overweight individual who begins an exercise program usually makes better use of food intake and utilizes stored fat for energy. An underweight individual or one whose weight is correct usually has an increase in appetite as a result of exercise. Also, an exhaustive program is not needed to be beneficial since the expenditure of calories through exercise is cumulative.[29]

The common practice of omitting meals in order to reduce is fallacious. Breakfast is generally the meal that is omitted in order to "cut down." Actually, breakfast is the most important meal of the day, and without it, the body is required to function without fuel. Three regular meals a

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[27] Jean Mayer, Overweight: Causes, Cost, and Control (Englewood Cliffs, N. J., 1968), p. 57.

[28] Ibid.

[29] David K. Miller and T. Earl Allen, Fitness: A Lifetime Commitment (Minneapolis, Minn., 1979), p. 89.

day of governed calories is the ideal method for reducing without injury to health.[30]

Two interesting studies were conducted in relation to comparison of subjects and the significance of per cent body fat in intercollegiate competition. Addae found that when Ghanaian subjects were compared with published figures for Caucasian subjects of similar age, the Ghanaian men had much less total body fat while the women had a little less total body fat than their Caucasian counterparts.[31] Niinimaa stated that body fat percentage, racing experience, and cardiorespiratory fitness were significant factors in racing success of intercollegiate cross-country skiers.

Techniques of Assessing Body Composition

The first and perhaps the best and most precise method for the evaluation of body composition (body fat) is by the underwater weighing method which is based on the low

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[30] Blanche J. Drury, Posture and Figure Control Through Physical Education (Palo Alto, Ca., 1970), p. 14.

[31] S. K., Addae, S. Dakubu, E. T. Larmie, R. Boatin, and E. H. Beleher, "Total Body Water, Total Exchangeable Sodium and Related Variables in the Ghanaian," Clin. Sci. Mol. Med., 54, 5 (May, 1978), p. 478.

[32] V. Niinimaa, M. Dyon, and R. J. Shepard, "Performance and Efficiency of Intercollegiate Cross-Country Skiers," Med. Sci. Sports, 10, 2 (Summer, 1978), p. 92.

specific gravity of adipose tissue.[33,34] In other words, the fact that fat is lighter than water, while muscle and blood are slightly heavier, and bones much heavier, can be used to determine total body fat. Weighing people first in air and then in water is a procedure first hinted at by Archimedes. It was pioneered by a U. S. Naval medical officer, Captain Albert Behnke, Jr., who had previously served in submarines, and thus, had presumably given much thought to the behavior of submerged bodies.[35] From the density of the individual underwater, that of fat, bone, and nonskeletal, nonadipose tissues, plus corrections for the air in the lungs, it is possible through appropriate formulas to determine the total amount of fat in the body. Further refinements to the original study of A. R. Behnnke has been devised by Keys and Brozek.[36,37] They found that no universally valid formulas for densiometric estimation of the fat content can be offered; however, the formula f (per cent body fat) = 4.570/D - 4.142 is most applicable

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[33]Mayer, Overweight, p. 30.

[34]Herbert A. DeVries, Laboratory Experiments in Physiology of Exercise (Dubuque, Iowa, 1971), p. 107.

[35]A. R. Behnke, B. G. Feen, and W. C. Welham, "The Specific Gravity of Healthy Men," JAMA, 118 (February, 1941), pp. 495-498.

[36]J. Brozek and A. Keys, Brit. J. Nutrition, pp. 194-206.

[37]J. Brozek, F. Grande, J. T. Anderson, and A. Keys, "Densiometric Analysis of Body Composition: Revision of Some Quantitative Assumptions," N. Y. Acad. Sci., 110, Part 1 (1963), pp. 113-140.

to the estimation of the fat content in individuals in whom the body weight has been free from large recent fluctuations, whether it is up or down. Behnke and Wilmore and Weltman and Katch found the validity of underwater weighing to be high (r = .88 to .99).[38,39]

Other laboratory methods of arriving at an estimation of total body fatness or per cent body fat are: hydrometry - the measurement of total body water by injecting a diluting substance, the concentration of which can be determined after it has become distributed throughout the body, and the determination of whole body potassium (potassium-40) which is an element contained in cells, while fat contains almost none of it. Whole body potassium is determined by counting gamma rays emitted by the radioactive isotope of potassium which accompanies the nonradioactive potassium of the body in small and constant proportion. Obviously, the greater the amount of potassium in relation to the total size of the body, the greater the amount of living protoplasm and the smaller the amount of fat.[40]

Although the laboratory methods are accepted as being valid, they are not always practical for mass testing due to the requirements of specialized equipment nor ordinarily

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[38] A. R. Behnke and J. H. Wilmore, Evaluation and Regulation of Body Build and Composition (Englewood Cliffs, 1974).

[39] A. Weltman and V. Katch, "Preferential Use of Casing (Girth) Measures for Estimating Body Volume and Density," J. Appl. Physiol., 18 (1967), pp. 560-563.

[40] Mayer, Overweight, p. 31.

available for field studies. Thus, techniques for predicting body density or per cent body fat have been developed that are more applicable for determining the nutritional status of large groups of subjects in a nonlaboratory setting. These include caliper measurements of subcutaneous skinfold fat and various anthropometric measures such as height, weight, bone diameters, and circumferences. The rationale for the use of such measurements is based on the high multiple correlations and low standard errors of prediction found between the simpler measurements and the criterion body composition determined by more complex techniques.[41]

Some methods that are available for large populations, for research in the field or facilities without proper equipment are: Kuntzleman method, Sharkey method, W. R. Best method, and the Conzolazio method.

The Kuntzleman method was developed by Charles T. Kuntzleman and involves using the sum of four skinfold measurements to predict the per cent body fat. His method was presented in the book Activetics in 1975.

A method that was presented in 1978 in Health and Fitness Through Physical Activity is the Sharkey method. This method uses the person's body weight and waist girth to obtain the per cent body fat by using a nomogram developed by Dr. Sharkey.

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[41] Frank I. Katch and W. D. McArdle, "Validity of Body Composition Prediction Equations for College Men and Women," Am. J. Clin. Nutr., 28 (1975), p. 105-109.

In the W. R. Best method, three skinfolds are measured, and by using the nomogram developed by W. R. Best the specific gravity and per cent body fat can be predicted. The method depends upon the fact that a high correlation exists between specific gravity and the various skinfold dimensions.[42]

Age, height, weight, and three (back, chest, and arm) skinfold measurements are used with a nomogram to determine per cent body fat in the Consolazio method. This method was presented in 1963 and has been used widely since that time.

Although individual statistics were not available for each of the previously mentioned methods, various studies have shown that methods using anthropometric body measurements give a dependable estimate of body density or per cent body fat as determined by more complex techniques. For young men, Brozek and Keys, Pascale, and Sloan found that two or three skinfolds gave the best prediction of body density (r = .85-.87); while Young and Blondin, Sloan, Katch and Michael, and Wilmore and Behnke observed that either skinfolds alone or combinations of skinfolds, circumferences and bone diameters resulted in the best

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[42]DeVries, Laboratory Experiments, p. 107.

predictions of body density for young women (r = .87-.98).[43,44,45,46,47,48,49]

Jackson and Pollock found that generalized equations provided valid and accurate body-density estimates with adult men varying in age and fatness.[50] The best evidence was provided by the standard error when an equation was cross-validated on a second sample. The standard errors for the cross-validation analysis were low and nearly identical to the standard errors found with the validation sample. This provided the strongest evidence that

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[43]J. Brozek and A. Keys, Brit. J. of Nutrition, pp. 194-206.

[44]L. R. Pascale, M. I. Grossman, H. S. Sloane, and T. Frankel, "Correlations Between Thickness of Skinfolds and Body Density in 88 Soldiers," Human Biology, 28 (1956), pp. 165-176.

[45]A. W. Sloan, "Estimation of Body Fat in Young Men," J. Appl. Physiol., 23 (1967), pp. 311-315.

[46]C. M. Young, M. E. K. Martin, R. Tensuan, and J. Blondin, "Predicting Specific Gravity and Body Fatness in Young Women," J. Am. Dietet. Assoc., 40 (1962), pp. 102-107.

[47]A. W. Sloan, J. J. Burt, and C. S. Blyth, "Estimation of Body Fat in Young Men," J. Appl. Physiol., 17 (1962), pp. 967-970.

[48]F. I. Katch and E. D. Michael, "Prediction of Body Density from Skinfold and Girth Measurements of College Females," J. Appl. Physiol., 25 (1968), pp. 92-94.

[49]J. H. Wilmore and A. R. Behnke, "An Anthropometric Estimation of Body Density and Lean Body Weight in Young Women," Am. J. Clin. Nutr., 23 (1970), pp. 267-274.

[50]A. S. Jackson and M. L. Pollock, "Generalized Equations for Predicting Body Density of Men," Brit. J. of Nutrition, 40 (1978), pp. 497-504.

generalized equations were accurate and valid for use with adult men varying in age and body density.

Damon and Goldman found that among ten methods commonly used to describe body configuration, that is, surface area, somatype, height-weight ratios, height and body circumferences, and skinfolds, the choice of skinfolds was best suited to predict body density and fat relative to hydrostatically determined methods.[51]

There are some possible sources of error and also limitations that might occur when dealing with various methods of predicting per cent body fat. One of the first problems would be the accuracy of measurement. Various aspects to be considered would be the use of one observer, good equipment, proper measurement sites, incorrect use of the instruments, and failure of the investigator to master the techniques involved in the particular measurement.[52,53,54]

A second area of concern would involve the selecting of a proper equation for the population being tested. Several studies have demonstrated that prediction equations are

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[51] A. Damon and R. T. Goldman "Predicting Fat From Body Measurements: Densitometric Validation of Ten Anthropometric Equations," Human Biology, 36 (1964), pp. 32-44.

[52] DeVries, Laboratory Experiments, p. 107.

[53] T. G. Lohman, J. H. Wilmore, and F. Roby, "Investigator Reliability of Skinfolds," Abstracts of Research Papers, 1979 AAHPER Convention (Washington, D. C., 1979), p. 102.

[54] W. E. Sinning, "Use and Misuse of Anthropometric Estimates of Body Composition," JOPER, 51 (February, 1980), p. 44.

specific to the populations from which they were derived (Damon and Goldman, 1964; Wilmore and Behnke, 1970; Zuti and Goldman, 1973; Pollock, 1975).[55,56,57,58] Application of equations to different age groups, sexes, races, or individuals of different fitness levels invites large amount of error.[59] Regression equations for the prediction of body density are specific even among athletes in the same sport.[60]

It should also be remembered that equations are used for a population and not necessarily for an individual within the population. Tcheng and Tipton and Sinning found that individual estimates could be extremely inaccurate.[61,62]

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[55] A. Damon and R. T. Goldman, pp. 32-44.

[56] J. H. Wilmore and A. R. Behnke, Am. J. Clin. Nutr., 23, pp. 267-274.

[57] W. B. Zuti and L. A. Golding, "Equations for Estimating Per Cent Fat and Body Density of Active Adult Males," Medicine and Science in Sports, 5 (1973), pp. 262-266.

[58] M. L. Pollock, E. E. Loughridge, B. Coleman, A. C. Linnerud, and A. Jackson, "Prediction of Body Density in Young and Middle-aged Women," J. Appl. Physiol., 38 (1975), pp. 745-749.

[59] M. M. Flint, B. L. Drinkwater, C. L. Wells, and S. M. Horvath, "Validity of Estimating Body Fat of Females: Effect of Age and Fitness," Human Biology, 49 (1977), pp. 559-572.

[60] H. L. Forsyth and W. E. Sinning, "The Anthropometric Estimation of Body Density and Lean Body Weight of Male Athletes," Med. Sci. Sports, 5 (1973), pp. 174-180.

[61] T. K. Tcheng and C. M. Tipton, "Iowa Wrestling Study: Anthropometric Measurements and the Prediction of a 'Minimal' Body Weight for High School Wrestlers," Med. Sci. Sports, 5 (1973), pp. 1-10.

[62] W. E. Sinning, N. F. Wilensky, and E. J. Meyers, "Post Season Body Composition Changes and Weight Estimation

The prediction of body density or body fat from anthropometric measurements is convenient and quick. Katch and Michael, Wilmore, and Katch and McArdle found that anthropometric measurements can also be inaccurate and misleading when predicted values are used to assess changes in body composition following physical conditioning programs.[63,64,65] Although anthropometric measurements may not be accurate in determining true body composition changes in the individual, they can be of use for the motivation of an individual when he sees a decrease in the skinfold measurements and body circumferences.[66]

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in High-School Wrestlers," Physical Education, Sports, and the Sciences (1976), pp. 137-153.

[63] F. I. Katch and E. D. Michael, J. Appl. Physiol., 25, pp. 92-94.

[64] J. H. Wilmore, R. N. Girandola, and D. L. Moody, "Validity of Skinfold and Girth Assessment for Predicting Alterations in Body Composition," J. Appl. Physiol., 29 (1970), pp. 313-317.

[65] F. Katch and W. D. McArdle, Am. J. Clin. Nutr., 28, pp. 105-109.

[66] W. E. Sinning, JOPER, 51, p. 45.

CHAPTER III

METHODOLOGY

The subjects were volunteers from the faculty and administration of Bethany Nazarene College, a small, private, church related, liberal arts college in central Oklahoma. There were 45 male faculty members and administrators who were in the population used for the study. This represents 87 per cent of the total population. The age range was from 26 to 68 years of age. The mean age was 43.

Personal Data Collected

Each subject was asked to fill out a personal physical fitness activities form. The form included such items as age, occupation and/or department, height, weight, and present physical and recreational activities. The form was used for placement of each subject in the physical activity pattern groups.

Test Administration

The subjects were asked to sign up for a specific time to be tested. The testing was conducted in Broadhurst Gymnasium on the campus of Bethany Nazarene College. The swimming pool in the gymnasium was used for the underwater weighings. All subjects were informed of the procedures that would be followed, and any questions were answered before testing began. To insure reliability of the investigator, 10 subjects were tested and retested four days later. This was done with all methods of testing used in the study to determine per cent body fat. The testing was conducted in the following order:

1. Sharkey method (body weight and waist girth)
2. Kuntzleman method
3. W. R. Best method
4. Consolazio method
5. Underwater weighing

Sharkey Method

The subject was weighed to obtain body weight and also measured to obtain waist girth. These two figures were then marked on Sharkey's nomogram. A line was drawn from the waist girth measurement to the body weight and the per cent body fat was then obtained from the point at which the line bisected the per cent body fat reference line (see the Appendix, page 60).[1]

[1]Michael L. Pollock, Jack H. Wilmore, and Samuel M. Fox III, Health and Fitness Through Physical Activity (New York, 1978), p. 104.

Kuntzleman Method

The Harpenden Skinfold Caliper was used to obtain skinfold thicknesses at four places: the arm (tricep) - vertical fold on the posterior midline of the upper arm (over tricep), halfway between the acromion and olecranon process with the elbow extended and relaxed, the abdomen - vertical fold adjacent to and approximately two inches laterally from the umbilicus, the arm (bicep) - vertical fold on the anterior midline of the upper arm (over bicep) halfway between the acromion and olecranon process with the elbow extended and relaxed, and the subscapular (back) - fold taken on a diagonal line coming from the vertebral border one inch from the inferior angle of the scapula. The four measurements obtained were added together. The total of the four measurements was used in a chart to arrive at the per cent body fat of the subjects (see the Appendix, page 63).[2]

W. R. Best Method

The Harpenden Skinfold Caliper was used to obtain skinfold thicknesses at three places: the arm (tricep) - vertical fold on the posterior midline of the upper arm (over tricep), halfway between the acromion and olecranon process with the elbow extended and relaxed, the abdomen -

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[2]Charles T. Kuntzleman, Activetics (New York, 1975), p. 58.

vertical fold adjacent to and approximately two inches laterally from the umbilicus, and the chest - diagonal fold one-half of the distance between the anterior-axillary line and nipple. From these measurements, a nomogram was used to figure the specific gravity and per cent body fat (see the Appendix, page 64).[3]

Consolazio Method

The subject's age, height, and observed body weight were used to determine relative body weight per cent. With the subject's relative body weight per cent; chest - diagonal fold one-half of the distance between the anterior-axillary line and nipple; arm (tricep) - vertical fold on the posterior midline of the upper arm (over tricep), half-way between the acromion and olecranon process with the elbow extended and relaxed; and back (subscapular) - fold taken on a diagonal line coming from the vertebral border one inch from the inferior angle of the scapula, skinfold measurements, the subject's specific gravity and per cent body fat were determined from a nomogram (see the Appendix, pages 61 and 62).[4]

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[3]W. R. Best, "An Improved Caliper for Measurement of Skinfold Thickness," USAMRNL, Report No. 113, August 31, 1953.

[4]C. Frank Consolazio, Robert E. Johnson, and Lewis J. Pecora, Physiological Measurements of Metabolic Functions in Man (New York, 1963), p. 304.

Underwater Weighings

The subjects were weighed out of the water, and then ten readings or enough readings to obtain a consistent reading were made while the subject was in the water. The highest (heaviest) reading obtained at least two times, with the subject under water and air expired, was used to subtract from the constant weight of the seat and harness to obtain the underwater weight. Due to the complexity, equipment, and time involved, the residual volume was estimated. It has been shown that for screening purposes, the use of a constant assumed average residual volume or the estimate of residual volume from the vital capacity provides an acceptable substitute for the actual, determined residual volume.[5] With this net weight in water plus the weight in air, a formula was used to obtain specific gravity and per cent body fat of the subject (see the Appendix, page 66).[6,7]

The methods used in this study have been published in various forms of literature and have been found to have

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[5] J. H. Wilmore, "Use of Actual, Predicted, and Constant Residual Volumes in the Assessment of Body Composition by Underwater Weighing," Med. Sci. Sports, 1 (1969), p. 88.

[6] A. R. Behnke and Jack H. Wilmore, Evaluation and Regulation of Body Build and Composition (Englewood Cliffs, N. J., 1974), p. 22.

[7] J. Brozek, F. Grande, J. T. Anderson, and A. Keys, "Densiometric Analysis of Body Composition: Revision of Some Quantitative Assumptions," N. Y. Acad. Sci., 110, Part 1 (1963), pp. 113-140.

high validity in predicting per cent body fat. The ability to predict accurately the relative leanness or fatness of both males and females of different ages through the use of various measurements has been demonstrated repeatedly. The validity of predicting per cent body fat for the various methods was as follows: W. R. Best method, r = .98; Consolazio method, r = .94; Kuntzleman method, r = .96; and Sharkey method, r = .90.[8,9,10,11]

Data Treatment

In dealing with the four methods of obtaining per cent body fat, a correlation coefficient was calculated between each of the four methods being tested and the underwater weighing method to determine if there was and is a close or high relationship in these five methods of determining per cent body fat. The mean, standard deviation, and variance

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[8] R. C. Steinkamp, N. L. Cohen, W. R. Garrey, T. McKey, G. Bron, W. E. Siri, T. W. Sargent, and E. Issacs, "Measures of Body Fat and Related Factors in Normal Adults, II. A Simple Clinical Method to Estimate Body Fat and Lean Body Mass," J. Chronic Diseases, 18 (1965), pp. 1291-1307.

[9] J. H. Wilmore and A. R. Behnke, "An Anthropometric Estimation of Body Density and Lean Body Weight in Young Men," J. Appl. Physiol., 27 (1969), pp. 25-31.

[10] J. H. Wilmore and A. R. Behnke, "An Anthropometric Estimation of Body Density and Lean Body Weight in Young Women," Am. J. Clin. Nutr., 23 (1970), pp. 267-274.

[11] J. H. Wilmore, R. N. Girandola, and D. L. Moody, "Validity of Skinfold and Girth Assessment for Predicting Alterations in Body Composition," J. Appl. Physiol., 29 (1970), pp. 313-317.

were also calculated for each of the four methods tested in the study.

Ten subjects were tested and retested four days later by each of the five methods in the study. A correlation coefficient was then done on the test - retest of each method to determine the reliability and/or consistency of the investigator.

The age groups were arbitrarily chosen to be 25-34, 35-44, 45-54, and 55-68. The last category was originally set at 65, but two subjects were over 65. Subjects were designated as faculty members if they taught at least six hours, and all other subjects were classified as administrators. The faculty members from different departments were also compared on per cent body fat. Per cent fat of those on varying activity patterns were also compared. A person making over 30 points per week was placed in an active category, a person making from 16 to 30 points per week was placed in a moderate category, and a person earning 15 points or less per week was placed in the inactive category. The points are in reference to Dr. Kennth Cooper's point system as outlined in The Aerobics Way.[12]

An analysis of variance or F ratio was used to determine if there was any significant difference between the four age groups. Since there was a significant difference,

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[12]Kenneth H. Cooper, The Aerobics Way (New York, 1978), p. 228.

a t test was used to determine between which groups there existed a significant difference.

The t ratio was used to test for significance of difference of the activity patterns, and also, the faculty members versus the administrators. Only the mean, standard deviation, and variance were used to compare the per cent body fat of faculty members from various departments.

Description of Instruments

Skinfold Calipers: It is an instrument made for the measurement of skinfold thickness. The caliper is so made that a constant pressure of 10 gm/sq mm of force is exerted at all openings. (#3496, Harpenden Skinfold Caliper, Quinton Instruments, Seattle, Washington)

Underwater Weighing Scale: The scale is used to weigh the subject while under water. (Chatillon, New York, U. S. A.)

Anthropometric Tape: A flexible metal measuring tape marked in centimeters that was used to obtain body circumferences. A spring tension is used to make sure the same pressure is applied in all measurements.

CHAPTER IV

RESULTS

The purpose of the study was to determine the validity of four methods (Sharkey method, Kuntzleman method, W. R. Best method, and Consolazio method) of predicting per cent body fat in men using underwater weighing as a criterion. The subproblems in the study were: (1) To compare the results of the per cent body fat between four age groups: 25-34, 35-44, 45-54, and 55-68. (2) To compare the results of the per cent body fat between inactive, moderate, and active activity patterns of individuals tested. The results of the per cent body fat were also compared between faculty members and administrators and between faculty members of different departments.

To test the consistency and/or reliability of the investigator, 10 subjects were tested, and then, retested four days later. The correlation of each method was above .90. The Kuntzleman method was r = .948; Consolazio method, r = .940; Sharkey method, r = .998; W. R. Best method, r = .947; and Underwater weighing, r = .970. See Table I for the correlation coefficients and the mean, standard deviation, and variance of each method for both tests.

TABLE I

TEST - RETEST OF FIVE METHODS

Method	r	n	$\bar{X}$	S.D.	Var.
Kuntzleman	.948				
Test		10	20.0	5.50	27.20
Retest		10	20.9	5.65	28.69
Consolazio	.940				
Test		10	19.2	4.92	21.76
Retest		10	18.4	4.79	20.64
Sharkey	.998				
Test		10	20.9	5.04	22.89
Retest		10	21.6	5.40	26.24
W. R. Best	.947				
Test		10	13.8	5.53	27.56
Retest		10	11.9	5.09	23.29
Underwater Weighing	.970				
Test		10	24.0	5.91	31.4
Retest		10	24.6	7.06	44.84

The validity of the four methods was tested by finding the relationship of each method with the underwater weighing, since the underwater weighing was used in this study as the best criterion for measuring per cent body fat. The correlation of each group was above .80, which is considered a high relationship. The correlation for each group with the underwater weighing was as follows: Kuntzleman method, r = .894; Consolazio method, r = .848; Sharkey method, r = .807; W. R. Best method, r = .853. The preceding data along with the standard deviation, variance, and mean of each method is shown in Table II.

TABLE II

METHODS COMPARED TO UNDERWATER WEIGHING

Method	r	S.D.	$\bar{X}$	Var.
Kuntzleman	.894	5.09	21.04	25.33
Consolazio	.848	4.63	19.33	20.93
W. R. Best	.853	5.26	13.29	27.05
Sharkey	.807	4.98	20.87	24.29
Underwater Weighing		5.50	24.49	29.63

An analysis of variance, Table III, was calculated to see if there was any significant difference between the four different age groups (group one: 25-34, group two: 35-44, group three: 45-54, group four: 55-68). The analysis of variance procedure yielded a mean square between groups of 124.95 and a mean square within groups of 23.91. An F value of 5.23 was determined, which indicated a significant difference between the four different age groups from the

.05 level (2.84) through the .05 level (4.31). A significant difference was also indicated as high as the .005 level (4.98).

TABLE III

ANALYSIS OF VARIANCE OF PER CENT BODY FAT BETWEEN AGE GROUPS

	S.S.	df	ms	F ratio	p
Between Groups	374.85	3	124.95	5.23	<.005
Within Groups	980.35	41	23.91		
Total	1355.20	44			

The t test yielded a t value of 2.02 at the .05 level of confidence and a t value of 2.62 at the .01 level of confidence. The critical difference determined with the t value was 4.22 at the .05 level and 5.64 at the .01 level of confidence. From these figures, it was determined that there was a significant or critical difference between group one and all of the other groups at the .05 level of confidence. At the .01 level of confidence, there was a significant difference between groups one and three. There was not a significant difference shown at either the .05 or .01 level of confidence for any other group. These results along with the mean, standard deviation, variance sum of each group can be found in Tables IV and V.

TABLE IV

STANDARD ERROR, t VALUE, AND CRITICAL DIFFERENCE OF MEANS

	.05 Level of Confidence	.01 Level of Confidence
Standard Error	2.09	2.09
t Value	2.02	2.62
Critical Difference	4.22	5.64

Group 1 (25-34) vs Group 2 (35-44)

4.73 difference: significant at the .05 level
not significant at the .01 level

Group 1 vs Group 3 (45-54)

8.09 difference: significant at the .05 level
significant at the .01 level

Group 1 vs Group 4 (55-68)

5.53 difference: significant at the .05 level
not significant at the .01 level

Group 2 vs Group 3
3.36 difference: not significant at the .05 or .01 level

Groups 2 vs Group 4

.8 difference: not significant at the .05 or .01 level

Groups 3 vs Group 4

2.56 difference: not significant at the .05 or .01 level

TABLE V

AGE GROUP MEANS, STANDARD DEVIATION, VARIANCE, AND SUM

Age	$\overline{X}$	S.D.	Var.	n	Sum
25-34	19.91	8.10	59.72	11	219
35-44	24.64	3.52	11.52	14	345
45-54	28.00	3.49	11.09	11	308
55-68	25.44	2.24	4.47	9	229

The activity patterns of the subjects were classified into three groups consisting of inactive, moderate, and active. The inactive group made 15 or less aerobic points per week, the moderate groups made 16 to 30 points per week, and the active group made 31 or more aerobic points per week. A t test was run to see if there was a significant difference in per cent body fat. The t test yielded a t value of .03 between the inactive and moderate groups, a t value of 1.66 between the inactive and active groups, and a t value of 1.06 between the moderate and active groups. At the .05 level a t value of 2.04, 2.02, and 2.23, respectively, was needed to show a significant difference. It was determined from this information that there was not a significant difference between any groups at the .05 level. See Table VI.

TABLE VI

t TEST BETWEEN ACTIVITY GROUPS, MEANS, STANDARD DEVIATION, AND VARIANCE

Group	$\bar{X}$	S.D.	Var.	n
Inactive	25.58	4.48	19.46	33
Moderate	25.50	4.36	14.25	4
Active	19.38	7.60	50.48	8

Inactive vs Moderate: not significant	
t value	.03
Significant t value .05 level of confidence	2.04
Inactive vs Active: not significant	
t value	1.66
Significant t value .05 level of confidence	2.02
Moderate vs Active: not significant	
t value	1.06
Significant t value .05 level of confidence	2.23

A t test was also run between the faculty members and the administrators. The t test yielded a value of .95, and a t value of 2.02 was needed to be significant at the .05 level of confidence; therefore, no significant difference was found between per cent body fat of faculty members and administrators at the .05 level of confidence. The t test information and means of each group may be found in Table VII.

TABLE VII

FACULTY VS ADMINISTRATORS t TEST, MEANS, STANDARD DEVIATION, VARIANCE, AND SUM

Group	n	S.D.	Var.	$\bar{X}$
Faculty	33	5.36	27.82	24.00
Administrators	12	6.11	34.19	25.75

Faculty vs Administrators: not significant

t value	.95
Significant t value .05 level of confidence	2.02

The subjects were also classified according to departments, but due to lack of members in some departments, only the mean of each department was considered when comparing departments. Also, some departments were grouped together to make one department. The results are shown in Table VIII.

TABLE VIII

DEPARTMENT DATA - PER CENT BODY FAT

Department	n	$\overline{X}$	S.D.	Var.
Math	3	22.00	3.61	8.67
Business	4	22.25	6.18	28.69
Sciences	5	25.00	5.52	24.40
Biology Physics Chemicstry				
Physical Education	3	17.67	11.72	91.55
Political Science And/or History	4	26.00	1.83	2.50
Religion/ Philosophy	5	23.40	3.78	11.44
Speech Communication	1	28.00		
Psychology	1	26.00		
Education	2	26.00	5.66	16.00
Music	5	26.40	3.78	11.44

Discussion

The results obtained in this study would indicate that the four methods being tested had a close relationship with the underwater weighing method. With this close of a relationship among methods, a person without the equipment or facilities for underwater weighing would be able to figure his per cent body fat by using one of the methods tested in this study.

By combining the groups over 45, the per cent body fat for the age groups followed what is normally expected with age. Group one had the least amount of per cent body fat, and as the age increased, so did the per cent body fat. Group three was the only group out of sequence. This could possibly be due to the fact that of the 11 subjects in this category, seven were inactive and four were classified as moderate.

According to the data and statistics, there was no significant difference at the .05 level of confidence in per cent body fat between the three groups based on activity patterns. There should have been more difference in the per cent body fat found between groups of activity patterns and some of the disagreement might be due to the subjects' reporting their own activities. The subjects that do more activity should have less per cent body fat and also a bigger difference in the level of per cent body fat in comparison to inactive subjects.

The other areas of comparison were in relation to the faculty members and administrators and also the means of different departments. As reported earlier, there was no significant difference between faculty members and administrators, although the mean of the administrators was 1.75% higher than the faculty. In relation to the departments, the physical education department had the least amount of per cent body fat, which would be expected due to the nature of their job.

Although other studies by Jackson and Pollock and Brozek and Keys have had approximately the same means as this study, it was still a little discouraging to find the mean for the 45 subjects tested to be 24.47% body fat.[1,2] This is above the 15% for men that is normally considered acceptable. Only four out of the 45 tested were 15% or below. People should not always be satisfied with being the same as other studies because the per cent body fat found in the previous studies could also be high.

When testing, it is difficult to do skinfold measurements, especially on people that have a larger per cent body fat. Individuals that do skinfold testing should practice and be sure they are consistent. One problem that occurs in underwater weighing is to get nonswimmers to relax and exhale all of their air during the weighing. Some swimmers have difficulty in this area also. The easiest method to use is the Sharkey method, and this method also seems to have less chance of error for the inexperienced individual. Since the relationships and the means are close, as this

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[1]A. S. Jackson and M. L. Pollock, "Prediction Accuracy of Body Density, Lean Body Weight, andTotal Body Volume Equations," <u>Med</u>. <u>Sci</u>. <u>Sports</u>, 9, 4 (1977), pp. 197-201.

[2]J. Brozek and A. Keys, "The Evaluation of Leanness - Fatness in Man: Norms and Interrelationships," <u>Brit</u>. <u>J</u>. <u>of</u> <u>Nutrition</u>, 5 (1951), pp. 194-206.

study indicated, a person at home could easily learn to administer the Sharkey test for per cent body fat. Also, the Sharkey method does not require any elaborate or expensive equipment, and the person doing the test does not need the practice that is necessary in doing other methods.

As stated earlier, the relationships were high, but there was some difference between the means. All of the means were fairly close to the underwater weighing mean except the W. R. Best method. A correction factor of eight per cent might be called for when using this method. This correction has been developed from this study and research done at Oklahoma State University.

Another aspect of this study that should be remembered is the fact that the findings of several studies have shown that methods of predicting per cent body fat are population specific in relation to age, race, and athlete or nonathlete.[3,4,5,6]

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[3] J. V. Durnin and J. Womersley, "Body Fat Assessed From Total Body Density and Its Estimation From Skinfold Thickness: Measurements on 481 Men and Women Aged from 16 to 72 Years," Brit. J. Nutr., 32 (1974), pp. 77-92.

[4] M. L. Pollock, A. Jackson, J. Ayres, A. Ward, A. Linnerud, and L. Gettman, "Body Composition of Elite Class Distance Runners," Ann. N.Y. Acad. Sci., 125 (1978), pp. 120-130.

[5] M. L. Pollock, E. Laughridge, B. Coleman, A. C. Linnerud, and A. Jackson, "Prediction of Body Density in Young and Middle-aged Women," J. Appl. Physiol., 38 (1975), pp. 745-749.

[6] M. L. Pollock, T. Hickman, Z. Kenrick, A. Jackson, A. C. Linnerud, and G. Dawson, "Prediction of Body Density in Young and Middle-aged Men," J. Appl. Physiol., 40 (1976), pp. 300-304.

The subjects in this study were very receptive to the testing and were interested in the results. As mentioned in the methodology chapter, 87 per cent of the population participated in the study, which was a total of 45. Of the men who did not participate, six were out of town, and one man could not put his head under water.

Some problems that might be considered if doing a study such as this would be centered mostly around the underwater weighings. When testing someone, the chain and seat connected to the scale should be held steady until the person is submerged. This will help in stabilizing the needle on the scale; therefore, making it easier to obtain a reading. Another area to be considered would be the depth of water used to do the underwater weighings. Some individuals might feel more comfortable in shallow water as opposed to deep water.

My recommendation in Chapter V are largely a product of areas not researched adequately in present studies. The first recommendation would help give some insight into possible benefits or detriments of certain occupations in relation to per cent body fat. Since this study only involved adult males, the recommendations concerning elementary and junior high students and female subjects were made. Also, the recommendation concerning elementary and junior high students was made due to scarcity of research with these populations. Recommendations were also made to compare the validity of underwater weighing of nonswimmers and swimmers and to do this same study on various racial and social economic groups. Comparing the validity of underwater weighing of nonswimmers and swimmers should be done to see if differences might occur due to familiarity with the water. The last recommendation would be interesting to conduct to see if the methods used in this study would be accurate with other populations and also what the mean per cent body fat would be in these groups.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of the study was to determine the validity of four methods (Sharkey method, Kuntzleman method, W. R. Best method, and Consolazio method) of predicting per cent body fat in men using underwater weighing as a criterion. The subproblems in the study were to compare four age groups, three categories of activity patterns, faculty members versus administrators, and faculty members of different departments.

Based on the findings of the study, the hypothesis that there would not be a high ($r = .80$ or above) correlation between the four methods being tested and underwater weighing was rejected.

The results of the tests administered to the 45 volunteer subjects would warrant the following conclusions.

1. The four methods tested have a high correlation (Kuntzleman method, $r = .894$; Consolazio method, $r = .848$; W. R. Best method, $r = .853$; Sharkey method, $r = .807$) with underwater weighing.

2. The per cent body fat in an individual increased with age when those over 45 were considered as one group.

3. There was not a significant difference between the active group and all other groups consisting of the moderate and inactive groups.

4. There was no significant difference in per cent body fat between the faculty members and the administrators.

Recommendations

1. Conduct a study using a population of varying occupations.

2. Conduct a similar study using female subjects.

3. Develop a method similar to the Sharkey method for women.

4. Conduct a similar study using elementary and junior high school age subjects.

5. Compare the validity of underwater weighing of swimmers and nonswimmers.

6. Test the validity of different methods (Sharkey method, Kuntzleman method, W. R. Best method, and Consolazio method) of predicting per cent body fat with various racial and social economic groups.

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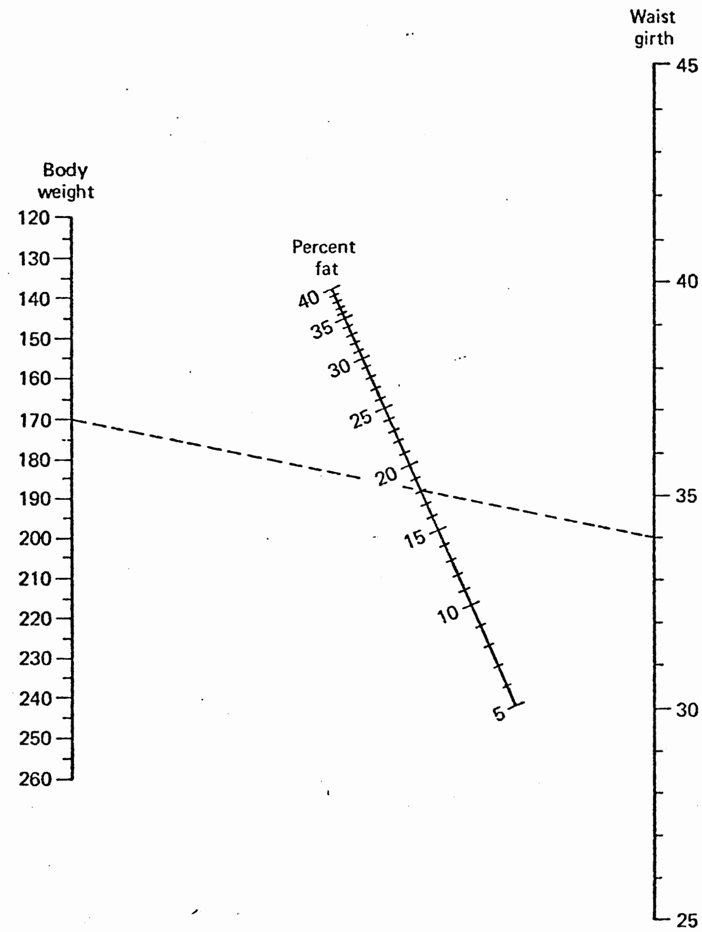
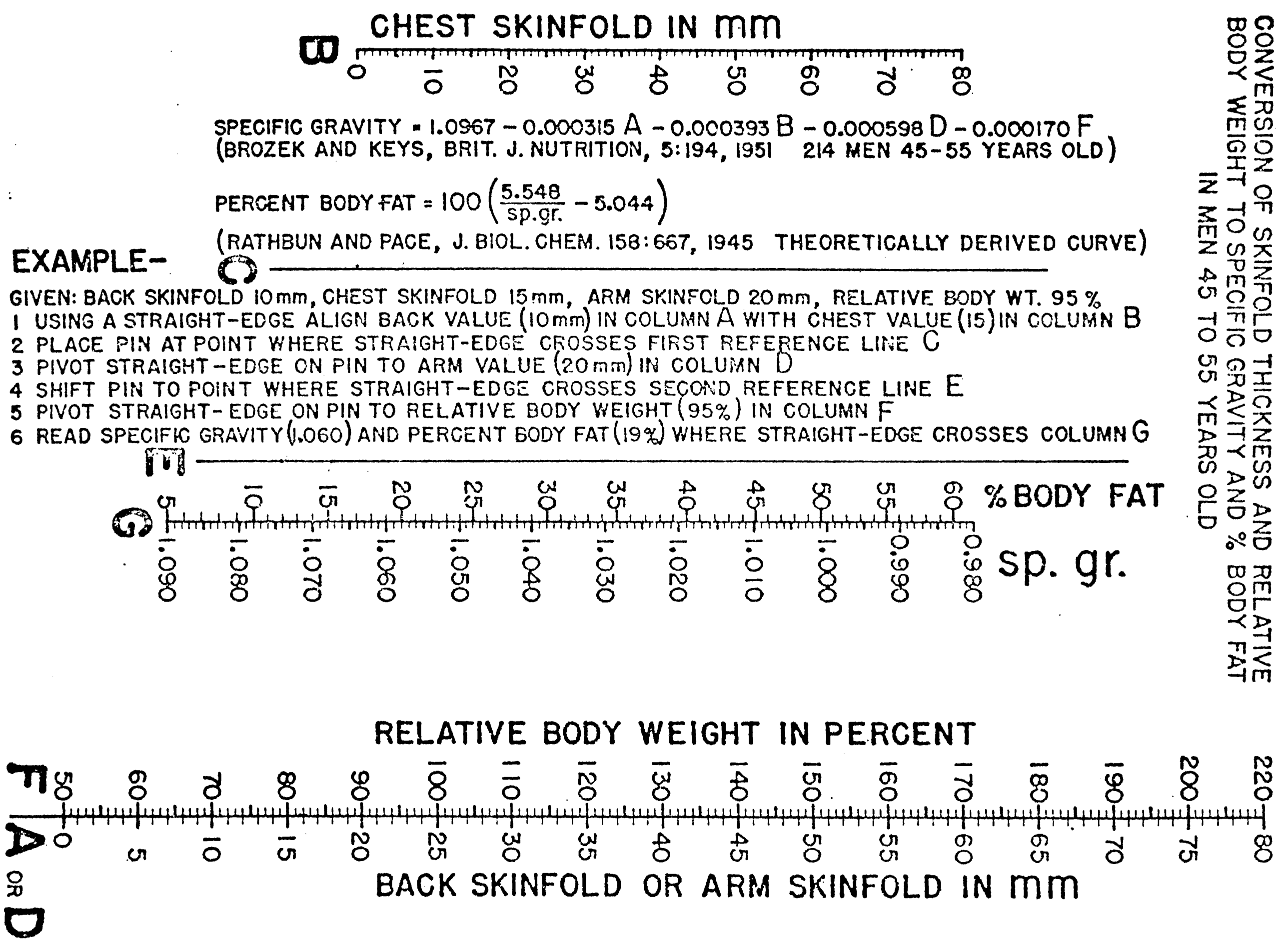
APPENDIXES

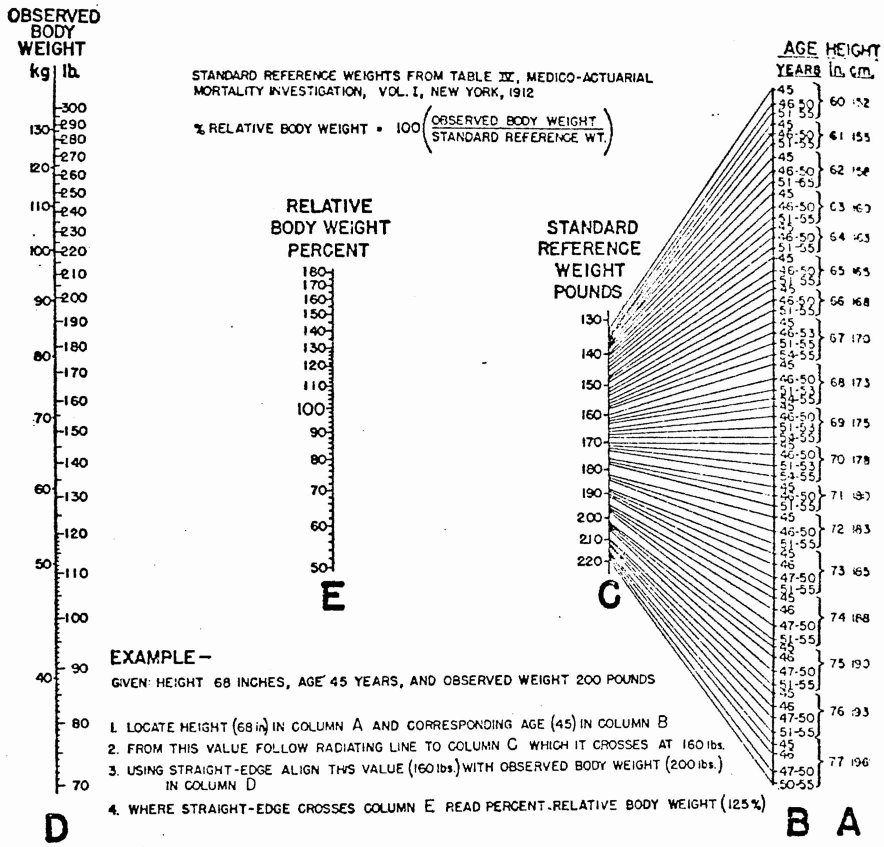


Prediction of relative body fat in men from waist girth and body weight. (Dr. Brian J. Sharkey, University of Montana, Missoula, Mo.)



CONVERSION OF SKINFOLD THICKNESS AND RELATIVE BODY WEIGHT TO SPECIFIC GRAVITY AND % BODY FAT IN MEN 45 TO 55 YEARS OLD

DETERMINATION OF RELATIVE BODY WEIGHT IN MEN AGED 45-55



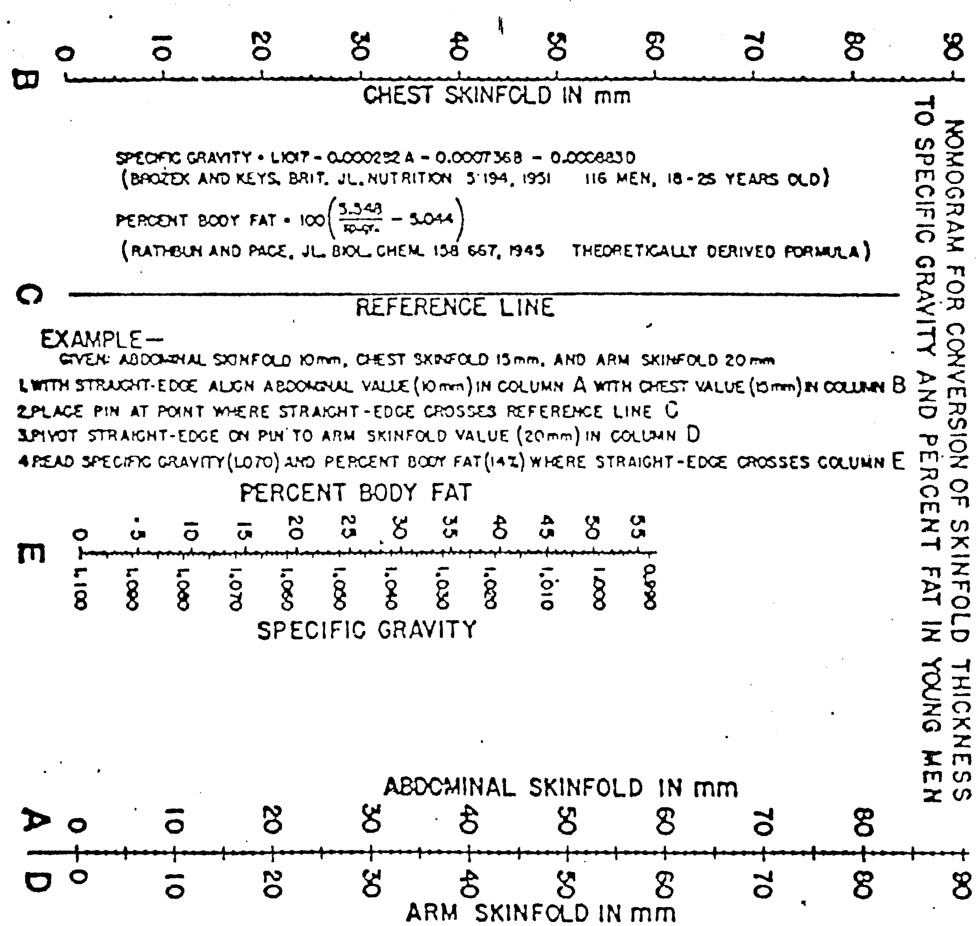
EXAMPLE –

GIVEN: HEIGHT 68 INCHES, AGE 45 YEARS, AND OBSERVED WEIGHT 200 POUNDS

1. LOCATE HEIGHT (68 in) IN COLUMN A AND CORRESPONDING AGE (45) IN COLUMN B
2. FROM THIS VALUE FOLLOW RADIATING LINE TO COLUMN C WHICH IT CROSSES AT 160 lbs.
3. USING STRAIGHT-EDGE ALIGN THIS VALUE (160 lbs.) WITH OBSERVED BODY WEIGHT (200 lbs.) IN COLUMN D
4. WHERE STRAIGHT-EDGE CROSSES COLUMN E READ PERCENT RELATIVE BODY WEIGHT (125%)

WOMEN Total mm.	% Fat	MEN Total mm.	% Fat
8	13	15	5
12	14	20	9
14	15	25	11
18	16	30	13
20	17	35	15
24	18	40	17
26	19	45	18
30	20	50	20
32	21	55	21
34	22	60	22
38	23	65	23
40	24	70	24
42	25	75	25
44	26	80	26
48	27	90	27
50	28	100	28
52	29	110	29
56	30	120	30
58	31	130	31
62	32	140	32
64	33	150	33
68	34	160	34
70	35	175	35
76	37	190	36
80	38	205	37
82	39	220	38
86	40	235	39
88	41	255	40
90	42	275	41
		295	42

From *Activetics,* by Charles T. Kuntzleman


NOMOGRAM FOR CONVERSION OF SKINFOLD THICKNESS TO SPECIFIC GRAVITY AND PERCENT FAT IN YOUNG MEN
B
0 10 20 30 40 50 60 70 80 90
CHEST SKINFOLD IN mm
SPECIFIC GRAVITY = 1.1017 - 0.000282 A - 0.000736 B - 0.000883 D
(BROZEK AND KEYS, BRIT. JL. NUTRITION 5:194, 1951 116 MEN, 18-25 YEARS OLD)
PERCENT BODY FAT = 100 (5.548 / SP. GR. - 5.044)
(RATHBUN AND PACE, JL. BIOL. CHEM. 158 667, 1945 THEORETICALLY DERIVED FORMULA)
C
REFERENCE LINE
EXAMPLE—
GIVEN: ABDOMINAL SKINFOLD 10 mm, CHEST SKINFOLD 15 mm, AND ARM SKINFOLD 20 mm
1. WITH STRAIGHT-EDGE ALIGN ABDOMINAL VALUE (10 mm) IN COLUMN A WITH CHEST VALUE (15 mm) IN COLUMN B
2. PLACE PIN AT POINT WHERE STRAIGHT-EDGE CROSSES REFERENCE LINE C
3. PIVOT STRAIGHT-EDGE ON PIN TO ARM SKINFOLD VALUE (20 mm) IN COLUMN D
4. READ SPECIFIC GRAVITY (1.070) AND PERCENT BODY FAT (14%) WHERE STRAIGHT-EDGE CROSSES COLUMN E
PERCENT BODY FAT
E
0 5 10 15 20 25 30 35 40 45 50 55
1.100 1.090 1.080 1.070 1.060 1.050 1.040 1.030 1.020 1.010 1.000 0.990
SPECIFIC GRAVITY
ABDOMINAL SKINFOLD IN mm
A
0 10 20 30 40 50 60 70 80
D
0 10 20 30 40 50 60 70 80 90
ARM SKINFOLD IN mm

Physical Activities Questionnaire

Name________________________________Date_________________

Home Address____

Home Phone_____________Age Last Birthday___________________

Date of Birth: Year___________Day__________________________

Position______________________Department___________________

Does your job require physical activity?___________________

Do you currently participate in any form of exercise on a regular basis?____

Check those done regularly and indicate no. of times per week of participation:

Walking____________________Basketball___________________

Jogging____________________Tennis_______________________

Swim_______________________Handball/racquetball_________

Golf_______________________Other (please name)__________

If you walk, jog, or swim, please indicate approximate distance covered each session and approximate pace.____________

Do you consider yourself to be overweight?__________________

If so, approximately how many pounds?________________________

OKLAHOMA STATE UNIVERSITY

PHYSICAL FITNESS EVALUATION CENTER
Underwater Weighing Record

Name:________________________________

Date:______________________ Ht.:___________Age:_____________

Nude Weight:___________lbs._________oz.(oz.=tenths of lb.)

A. Scale reading with seat and harness

Subject's weight readings in water:

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

B. Highest reading obtained at least two times______________

C. Underwater Weight (UW)-difference between A and B_________

D. Net weight in water = UW + 2.86 _______________

E. Specific Gravity (SG) = $\frac{\text{Wt. in air}}{\text{Wt. in air-net wt. in water}}$

____

F. Per cent of Body Fat = 100(4.570/SG-4.142)_______________

Subject	Height	Age	Weight	Underwater Reading	Chest mm	Abdomen mm	Arm mm (tricep)	Back mm	Waist Girth in.	Arm mm (bicep)
1	5'11"	44	194	10.00	12.00	18.00	12.00	15.60	37.50	6.00
2	6'4"	34	207	10.00	20.00	29.00	17.20	13.20	39.00	8.20
3	5'11"	43	185	9.50	14.40	23.00	13.80	19.00	37.75	6.80
4	5'7"	38	157	7.75	11.00	24.00	11.40	11.60	35.50	9.60
5	5'11	47	224	8.00	25.00	31.40	14.40	22.00	42.00	10.00
6	5'7"	26	119	11.00	4.60	6.60	4.80	7.20	28.00	3.00
7	5'11"	38	172	9.00	17.40	19.60	10.00	14.00	35.50	6.80
8	4'11"	28	237	10.00	27.00	27.00	13.00	27.00	42.50	10.80
9	6'1"	56	196	10.00	15.40	11.80	7.20	18.20	37.00	7.20
10	5'9"	32	148	10.50	7.80	9.00	6.20	11.20	31.00	3.40
11	5'6"	39	163	10.25	12.60	17.40	17.40	18.20	34.50	7.60
12	5'8½"	44	179	8.75	19.00	24.00	14.20	24.80	36.00	5.40
13	5'9"	40	176	11.00	12.80	20.80	9.80	16.40	34.50	6.00
14	5'10"	52	187	9.00	12.80	18.80	13.00	16.40	39.00	5.20
15	6'2"	35	156	9.50	10.60	15.80	12.00	10.20	32.00	4.00
16	6'2"	43	226	10.50	24.60	31.60	19.80	27.00	43.00	10.60
17	6'0"	28	126	11.00	4.40	5.20	6.20	7.80	27.50	2.80
18	6'3"	31	181	14.50	5.60	10.40	9.60	9.00	33.00	3.40
19	5'10½"	30	144	13.75	4.20	7.00	3.40	8.00	30.00	2.80
20	5'7½"	68	150	8.00	14.20	22.00	8.60	14.00	34.50	4.20
21	5'5½"	35	176	10.25	17.00	29.80	10.00	22.20	38.00	6.20
22	6'0"	29	150	11.00	5.40	7.80	7.40	8.80	31.00	3.60
23	5'9½"	53	175	11.00	13.40	17.40	10.80	10.60	34.00	5.00
24	6'0"	35	199	7.25	33.20	37.60	18.80	25.00	39.00	13.80
25	5'9"	47	182	9.00	22.20	22.40	11.00	27.20	39.00	6.60
26	5'8½"	48	190	8.00	34.00	34.00	16.40	30.00	40.00	8.80
27	5'8"	26	164	9.00	14.00	29.00	17.80	11.60	34.50	9.60
28	5'10"	55	179	8.00	21.60	30.20	18.40	17.40	37.00	9.00

Subject	Height	Age	Weight	Underwater Reading	Chest mm	Abdomen mm	Arm mm (tricep)	Back mm	Waist Girth in.	Arm mm (bicep)
29	6'2¾"	57	235	12.00	24.00	16.60	8.60	16.20	39.00	7.60
30	5'11"	33	226	7.50	25.00	33.60	23.00	28.60	43.00	13.20
31	6'2½"	61	185	11.00	15.40	15.20	7.40	12.80	35.00	6.80
32	6'0"	48	186	9.50	17.40	25.00	10.60	18.20	36.00	6.20
33	6'2"	37	184	10.50	14.20	28.60	15.20	15.60	37.00	6.20
34	6'0"	28	168	9.50	11.60	23.40	12.60	13.00	34.00	6.00
35	5'10½"	66	158	9.00	11.40	13.60	8.60	17.00	34.00	5.40
36	6'1"	52	177	9.00	15.40	22.00	20.00	12.40	35.00	7.20
37	5'4"	46	150	9.00	16.00	24.20	17.00	21.80	34.00	7.80
38	6'0"	47	265	9.00	27.00	39.00	15.00	40.00	44.50	8.20
39	5'10½"	54	214	7.50	34.00	45.00	10.00	23.20	41.75	7.40
40	5'5"	59	150	7.50	15.60	22.40	13.80	23.80	35.50	6.40
41	6'0"	55	155	9.25	9.60	19.80	9.00	10.00	32.50	4.40
42	5'11"	48	211	7.50	23.00	34.00	19.00	32.00	40.00	9.00
43	5'9½"	43	200	10.50	20.00	26.00	10.00	21.00	39.00	9.80
44	5'10½"	37	176	9.00	14.00	22.00	14.00	17.00	36.50	5.80
45	6'0"	55	94	10.00	15.00	20.00	10.50	17.00	37.00	4.50

Faculty: F

Administration: A

Inactive: I

Moderate: M

Active: A

Subject	Position	Activity Group	Department
1	F	I	Math
2	F	I	Business
3	A	I	Chaplain
4	F	I	Biology
5	F	M	Phys. Ed.
6	A	A	Dir. Media
7	F	I	Pol. Sci.
8	F	I	History
9	A	I	Financial Aids
10	F	I	Religion
11	F	M	Religion
12	F	A	Speech
13	F	A	Music
14	F	M	Philosophy
15	A	A	Comptroller
16	F	I	Music
17	F	I	Business
18	F	A	Phys. Ed.
19	F	A	Phys. Ed.
20	F	I	History
21	F	I	History
22	F	I	Math
23	F	M	Education
24	F	I	Chemistry
25	A	I	President
26	F	I	Education
27	A	I	Recruitment
28	A	I	Asst. to Pres.
29	F	I	Business
30	A	I	Development
31	F	I	Religion
32	F	A	Music
33	F	I	Math
34	A	I	Maintenance
35	F	A	Music
36	F	I	Psychology
37	F	I	Chemistry
38	A	I	Dean of Stu.
39	F	I	Music
40	F	I	Religion
41	A	I	Academic Dean
42	A	I	Bus. Mgr.
43	F	I	Biology
44	F	I	Physics
45	F	I	Business

VITA

John William Dunn

Candidate for the Degree of

Doctor of Education

Thesis: FOUR METHODS OF PREDICTING PER CENT BODY FAT IN MEN AS COMPARED TO UNDERWATER WEIGHINGS

Major Field: Higher Education

Minor Field: Health, Physical Education, and Recreation

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma, November 13, 1948, the son of Dr. and Mrs. Lester L. Dunn.

Education: Graduated from Bethany High School, Bethany, Oklahoma, in May, 1967; received Bachelor of Science degree in Physical Education from Bethany Nazarene College in 1971; received Master of Education in Physical Education from Central State University in 1977; completed requirements for the Doctor of Education degree at Oklahoma State University, May, 1980.

Professional Experience: Physical Education instructor, John Glenn Elementary School, Western Heights School District, 1972-73; Physical Education Instructor, Bethany Nazarene College, 1976-79; Assistant Professor, Bethany Nazarene College, 1979-80; Head baseball coach, 1976-77, Head cross-country and track coach, 1977-80; Head women's basketball coach, Bethany Nazarene College, 1978-80.