DEVELOPMENT OF AN EQUATION TO PREDICT THE PERCENT BODY FAT OF 18-25 YEAR OLD TURKISH MALES THROUGH SKINFOLD TESTING

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THROUGH SKINFOLD TESTING

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This Research is Dedicated to:

My mother and father, Hayriye and Yasar Dogu,

and the people of Turkey,

whom I love dearly.

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CHAPTER I

INTRODUCTION

The body is said to be the product of its nutrition. Though the transformations are profound, nutrition begins with the foodstuffs and proceeds to the material end results, the living body and its functions. The most elementary, but certainly not the least important, aspect of nutrition is the gross mass of tissue it produces and maintains. The most obvious, and in many populations perhaps the most common, nutritional defects are those caused by gross calorie imbalance.

Undernutrition is the most common form of malnutrition in underdeveloped countries, but even in the midst of plenty, starvation caused by disease is common because many illnesses interfere with the appetite or the assimilation of food. In the simplest of societies obesity may be rare, either because of chronic food shortage or because a physically strenuous life style is an effective preventive. But as societies become more specialized, more prosperous and more sedentary, an excessive accumulation of fat tends to be the rule unless it is consciously combated. D. B. Jelliffe (1966), in his book "The Assessment of the Nutritional Status of the Community" agreed that those problems of malnutrition which are often substantial causes of illness and death in developing regions of the world are those due to undernutrition, specific deficiency and imbalance, where as the problems of overnutrition are responsible for increasing morbidity and mortality in the better fed parts of the world such as U.S.A. and Western Europe.

Human malnutrition is always an ecological problem in that it is the end result of multiple overlapping and interacting factors in the community's physical, biological and cultural environments (Bengoa, 1940).

Thus, the amount of various foods and nutrients available to persons of different age-groups will depend upon such environmental conditions as climate, soil, irrigation, storage, transport and economic level of the population as well as cultural influences.

In large areas of the world today, malnutrition is one of the principle public health problems. It is either in the form of over-nutrition or obesity which is usually the case in developed countries such as U.S.A. and Germany. Or it is in the form of undernutrition which is usually the case in non-developed countries such as India, Banladesh, and Egypt. Energetic attempts to improve the situation are underway, mostly in developed countries and in some non-developed countries. These efforts should be intensified and more accurately and logically guided so that the most effective and appropriate preventative methods can be applied where the need is greatest.

In assessing public nutritional status, there are various tests used that are recommended by scientists and experts of health organizations. The World Health Organization Expert Committee on Medical Assessment of Nutritional Status (1963) recommended the study of body composition, including information concerning the amount of the distribution of human subcutaneous fat, and hence of calorie reserves.

Body composition studies can be carried out by various methods such as physical and chemical analysis (by whole-body analysis at autopsy), ultrasonics, densitometry (by water displacement or underwater weighing), gaseous uptake of fat-soluable gases, radiological anthropometry (using soft-tissue exposures), and physical anthropometry (using skin-fold calipers).

Other than direct cadaver dissection, one of the most precise measurements of body composition is obtained by measuring the individual body density by means of underwater weighing. The technique is based upon the Archimedian principle that loss of weight in water is equivalent to the body volume. Density is then

$$\frac{\text{Body Weight Air}}{\text{Body Weight Air} - \text{Body Weight Water}} \qquad \text{(Siri, 1956)}$$

An individual's body density is highly correlated with his or her percent body fat and lean body mass. The density of fat is known and is substantially less than the density of water; therefore, fat floats. The density of lean tissue is known and greater than that of water; so lean tissue sinks. Simply, an obese individual will weigh very little. A lean individual will weigh a great deal when submerged in water. By using an equation that accounts for body density and the other principal factor that causes an individual to float or sink, the amount of air left in the lungs after forcibly exhaling, a fat percentage can be predicted.

Behnke et al. was the first to make adequate estimates of body density through underwater weighing in the late 1930's (Behnke et al., 1942). Then, such equations were developed by Rathburn and Pace (1945), Siri (1956) and Brozek et al., (1963).

While all the laboratory techniques such as underwater weighing, water displacement, radiographic, ultrasound, and gaseous uptake of fat-soluable gases can be important tools in detailed nutritional investigation in well-equipped research centers, physical anthropometry using skinfold calipers is the most practical in field circumstances.

But, as Katch and McArdle (1973) suggested, the anthropometric equations used for calculation of percent body fat are very population specific. That is, the equation predicts the percentage of body fat accurately for the population used in forming the equation and may be inaccurate on any other group of people. This is due to variables such as bone structure, height, weight, age, sex, race, and location of the individual's fat stores (Willmore and Behnke, 1968; Durnin and Womersley, 1978; Fleck and Hagerman, 1980).

Since there had been no formulae developed previously for the Turkish population, it was important to do this study and develop the formulae specific for the Turkish male population. Even though, it is only for 18 - 25 year old males, it is a start to meet the needs of the Turkish population.

Statement of the Problem

The problem was to develop an equation to predict the percent body fat of 18 - 25 year old Turkish males through skinfold testing by using underwater weighing measurements as the criterion.

Sub-Problems

1. Skinfold fat thicknesses were compared on the subjects who

were: a) university students, b) non-student urban males, and c) non-student rural males.

2. Skinfold fat thicknesses were compared on males from seven geographical regions of Turkey.

3. The validity was checked for the Japanese (Nagamine et al., 1964), the British (Durnin et al., 1974), the American (Brozek et al., 1951) and the generalized (Pollock et al., 1979) equations in predicting the percent body fat of 18 - 25 year old Turkish males.

4. Skinfold fat thicknesses were compared on Turkish 18 - 25 year old males with other countries' measurements, where data is available.

Hypotheses

The null hypotheses were tested as follows:

1. There are no significant differences between the skinfold fat thicknesses of 18 - 25 year old males from seven geographical regions of Turkey.

2. There is no significant difference between the skinfold fat thicknesses of university students and non-student urban males.

3. There is no significant difference between the skinfold fat thicknesses of university students and non-student rural males.

4. There is no significant difference between the skinfold fat thicknesses of urban and rural non-student males.

5. There are no significant differences between the actual percent body fat values of 18 - 25 year old Turkish males that are measured through underwater weighing and the predicted percent body fat values of 18 - 25 year old Turkish males that are calculated through the Japanese (Nagamine et al., 1964), the British (Durnin et

al., 1974), the American (Brozek et al., 1951) and the generalized (Pollock et al., 1979) equations.

Delimitations

1. The subjects were 18 - 25 year old males.
2. The university student subjects were from Middle-East Technical University and other universities of Ankara.
3. The non-student urban subjects were from the city of Ankara.
4. The non-student rural subjects were from villages around Ankara.
5. Underwater weighing was the only method used as criterion to determine the body density and percent body fat for developing the regression equation.

Limitations

1. All the subjects were volunteers.
2. Physical activity patterns of the subjects were unknown during the selection of the subjects.
3. Residual lung volume was estimated rather than measured.
4. All body types may not have been proportionally represented.

Assumptions

1. The underwater weighing method was valid.
2. The researcher performed the underwater weighing technique validly and reliably.
3. The instruments used were accurate.

4. The researcher performed the skinfold measurement validly and reliably.

5. The subjects followed all pre-test instructions and exerted a maximum effort while being tested underwater.

6. The subjects represented the population from their area.

Significance of the Study

Health has been defined as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (Sandstead and Pearson, 1973). Because optimal nutrition is necessary for optimal health, assessment of many aspects of an individual's nutritional status can be done rather precisely in well equipped laboratory settings. For example: underwater weighing is an accurate laboratory method to assess an individual's body density and percent body fat. However, in evaluation of large population groups, field methods such as skinfold testing are not as limiting because of time, personnel and facilities.

Since, the regression equations used to predict percent body fat from skinfold thickness measurements are proven to be population speicific, new equations are needed to be developed for different population groups (age, racial, ethnic, etc.) to predict their percent body fat validly from skinfold thickness measurements.

Definition of Terms

Malnutrition: A pathological state resulting from a relative or absolute deficiency or excess of one or more essential nutrients.

Undernutrition: The pathological state resulting from the consumption of an inadequate quantity of food over extended period of time.

Specific Deficiency: The pathological state resulting from a relative or absolute lack of an individual nutrient.

Overnutrition: The pathological state resulting from the consumption of an excessive quantity of food, and hence a caloric excess over an extended period of time.

Imbalance: The pathological state resulting from a disproportion among essential nutrients, with or without the absolute deficiency of any nutrient as determined by the requirements of a balanced diet (Scrinshaw et al., 1966).

Obesity: An excess quantity of fat in the body (Bray, 1972).

Overweight: Weight in excess of normal range (may not involve obesity at all) (Mayer, 1968).

CHAPTER II

REVIEW OF THE LITERATURE

This review of literature is divided into the following two sections: 1) Nutrition and Health and, 2) Body Composition.

These sections are organized in light of cultural, environmental, racial, psychological, social, sexual, and age variations and their significance in different fields such as medicine, athletics, recreation, etc.

Nutrition and Health

Health has been defined by the World Health Organization (1946) as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Nutrition has been defined by the Council on Food and Nutrition of the American Medical Association (1963) as the science of food, the nutrients and other substances therein, their action, interaction, and balance in relation to health and disease, and the process by which the organism ingests, digests, absorbs, transports, utilizes, and excretes food substances.

The interrelationship between nutrition and health is that good health depends throughout the whole life span upon food adjusted to meet the needs of the body. The organism uses energy which comes from "food" in its broad sense, from the moment it is conceived until it dies.

According to Widdowson (1980), in addition to the energy the body requires specific nutrients, and relatively larger amounts are needed during the period of growth than after adult size had been reached.

Early in this century the application of nutrition research demonstrated the importance of adequate nutrient intake to the promotion of normal growth and development in infants and young children and to the protection of all segments of society against deficiency diseases.

In 1932 Bowles, an anthropologist, showed that freshmen students entering Harvard College were taller and heavier than their fathers were on admission to the same school in the early 1900's. Better food intake during infancy and childhood was one factor accounting for the difference between these two generations. Control of acute and chronic infectuous diseases and better obstetrical care were also important factors (Mitchell et al., 1976).

Many factors are doubtless responsible for changes in body size. Although there is still disagreement among scientists as to the limits of plasticity of the human organism, changes in size represents an increase under more favorable environment of the growth potential inherent in genes. According to Hathaway and Foard (1960), some of these environmental factors are improvement in socio-economic status, improvement in medical care and sanitation, greater availability and consequent consumption of nutritious foods, and improvement in the general knowledge of nutritional needs.

Ito (1942) demonstrated that Japanese women born and reared in California were taller and heavier than relatives born and reared in Hawaii, while those born and reared in Japan were smaller and lighter than the other two groups. The differences in these three groups are counted for in part by the quantity and quality of the good consumed during infancy and childhood.

Mitchell (1962) observed that when the nutritional needs of an adolescent are not met, stature potential is not realized. In Japan during World War II, food shortages resulted in a reduction in height among Japanese youth at all ages when compared to the pre-war stature of that age group. With increased prosperity resulting in more and better food after 1950, Japanese youth have grown taller than they have ever been before.

Nutrition is the dominating environmental influence that determines the rate of growth.

Studies in Holland (Mitchell, 1962; Smith, 1947b), Germany (Widdowson and Dickerson, 1964), and Russia (Widdowson and Crabb, 1976). showed that babies born in periods of severe food shortage were on the average smaller than those who were born in the same towns during the times of plenty.

There is a period of very rapid growth before and during sexual maturation, and hence relatively larger amounts are needed. Widdowson (1980) associated this puberty growth spurt with greatly increased appetite.

Marshall and Tanner (1974) reported that over the past 50 years boys and girls in developed countries have been growing faster and getting progressively taller and heavier at any given age, and men are now reaching their maximum height at 17 or 18 years, whereas 50 years ago it was not attained until the age of 26.

Even though good nutrition is very important through-out life, it is crucial during early periods of life. Chronic malnutrition in very early periods of life prevents the development of the full potentialities of the organism from morphological, mental, functional, and metabolical points of view - even when later adequate nutrition is ensured (Widdowson and McCance, 1963; Foman, 1974; Winick et al., 1974).

On the issue of fertility, Smith (1947a) reported that there was a decline in the birth rate in Rotterdam starting in June 1945. The lowest rates were in October-December 1945, corresponding the conceptions in the worst period of food shortage during the transport strike.

Turning to the other side of the picture, overnutrition, some clinicians blame obesity for their patients' sterility (Moll-Christensen, 1938). However, other clinicians have been more impressed with the fertility of fat women (Odel and Mengert, 1945). Also, nutrition is one of the environmental factors which is an essential component in the management of many diseases (coronary heart disease, cerebrovascular disease, hypertension, obesity, diabetes, anemia, rickets, allergy, gut disorders, cancer, liver disease, kidney disease, inborn errors of metabolism, convalescence) (Turner, 1980).

Nutrition of sportsmen, like that of every other person, is mainly aimed at providing the organism with an adequate quantity of energy, plastic materials, and essential nutrients. According to Rogozkin (1978) correctly organized nutrition for sportsmen during periods of intense physical and neuro-psychological loads increases their working capacity and creates the foundation for achieving high levels of physical performance.

The principles for creation of nutritional plans for athletes are listed by Rogozkin as follows:

1. Providing the sportsmen with necessary quantities of energy according to the energy expended during physical activity (Pokrovsky, 1976).
2. Adhering to the principles of balanced nutrition with reference to definite kinds of sport and intensity of physical loads. This means providing for distribution of calories in the ration with the reference to the main alimentary components (proteins, lipids, and carbohydrates), and the balance between the main nutrients, vitamins, and microelements (Pokrovsky, 1975).
3. Choosing adequate forms of nutrition (food products, nutrients, and their combinations) and number of feedings (3-6) during the time of intensive training; and pre-competition and competition periods (Litvinova et al., (1976).
4. The use of alimentary factors for rapid weight reduction to bring the sportsman to a specific body weight.
5. The application of the principles of individualized nutrition based on the anthropometric, physiological, and metabolic characteristics of the sportsman and the state of his digestive organs, tastes, and habits.

Astrand (1973) in his article wrote that sportsmen have been interested for at least "2000" years in the effect of nutrition on sports performance. It is safe to say that although these efforts are very old, an unequivocal answer to the question is still lacking. Workers have received less attention because their employers have traditionally shown little interest in the effect nutrition might have on working performance, and even less interest in workers' health status.

Christensen and Hansen (1939) and Bergstrom et al., (1967) agreed that the level of nutrition is one of the environmental factors able to modify the ability to perform strenuous work. An acute deficiency of several vitamins, particularly those of the B group, or variations in proportions of the daily requirements may elicit this effect.

It is very important to recognize that good nutrition throughout life is essential for proper growth and development, for a healthy puberty and adolescence, for optimal reproduction and healthy active adult life extending well into old age.

Body Composition

The study of body composition was born in human biology, in particular the biology of human growth. But it did not flourish in human biology, primarily because the tissue masses of body compartments seemed too elementary to merit sophisticated attention. Human biologists interested in taxonomically important characters ignored fat because it so obviously varied with the nutritional state. Human biologists concerned with morphogenesis neglected tissue measurements as anatomically too gross to explain variations in growth and form.

But as Kuhn (1962) pointed out in his book , progress in one scientific direction frequently creaks to a halt until a new set of ideas restores forward motion. This had been assuredly true of the study of body composition in human biology. Impetus for the study of fat (as other than a superficial variable) came from research relating the amount of fat to the probability of death. Motivation for the study of muscle came from the growing interest in dietary protein and the rate of muscle growth, and the stimulus for the investigation of bone mineral stemmed increasingly from the ubiquitous problem of osteoporosis, its cause, prevention and cure.

Physique is a complex phenomenon with innumerable parameters. The variability of these parameters of body composition and their relationship to hereditary, environmental, and developmental factors is the reason that its characterization will depend in a large measure on the investigation's purpose. Therefore, the concern of this investigation was principally the soft parts of the body, in particular, the adipose tissue.

Body Density

Ideally, the description of the body configuration and composition is best accomplished through the post mortem analysis and findings then correlated with the previously collected measurements on the living person (Hunt, 1961). Mitchell et al., (1945) and Forbes et al., (1956) provided much of the classical cadaver description of the gross composition and chemical constituents of the human. Other studies of body composition by direct cadaver dissection were completed by Pitts (1963) and Dempster and Gaughran (1965). The latter was a description of eight male cadavers establishing approximate standards for the weight, volume, and density of the different body segments and should be of interest to kinesiologists.

Since direct chemical analysis of the whole body or part of it is not possible with the living subjects, other methods have been developed. The use of body density as the determinant of body composition is considered to be one of the best experimental methods for the evaluation of relative body fat. Although, there are some inherent problems (Buskirk, 1961; Siri, 1961; Katch, 1968) and although the constants and assumptions used can be affected by variability in the amount of bone, the proportion of bone mineral, or by the state of hydration of the body (Brozek et al., 1953; Brozek et al., 1963; Girandola et al., 1977), analysis of the method has shown that it is sufficiantly reliable, and that the density of the lean body mass is relatively constant in healthy, young men (Behnke, 1945; Brozek and Keys, 1951).

Body density measurements were made on one hundred and fifty-one children ranging in age from nine to seventeen by Parizkova (1961). In males, body density fell from 1.062 gm/cc at age nine to 1.048 gm/cc at eleven to thirteen years of age. It then rose again to 1.073 gm/cc at age sixteen. The difference in girls was not so evident as body density changes little from 1.041 gm/cc until age twelve at which time it rose and peaked at 1.051 gm/cc during the thirteen and fourteen year age. It then fell again to 1.038 gm/cc at age seventeen.

Novak (1963) determined age and sexual differences in the body density of one hundred and ten high school children, fifty-seven boys and fifty-three girls. The age range was 12.5 to 18.5 years of age. It was found that the body density for boys increased from 1.0654 gm/

cc at 12.5 years of age to 1.0743 gm/cc at age fifteen and seventeen. In constrast, the body density for girls decreased from 1.0643 gm/cc at 12.5 years of age to 1.0409 gm/cc at seventeen years of age. A simultaneous increase in skinfold thickness was noted along with the decrease in body density suggesting that the decrease is due to greater amounts of body fat in the older girls.

Nagamine and Suzuki (1964) studied the body composition of ninety-six college men and one hundred and twelve college women in Tokyo. Age range for the men was eighteen to twenty-seven years of age and for the women the range was eighteen to twenty-three years of age. Density determinations were made by water displacement and mean body density was 1.0472 gm/ml for women and 1.0694 gm/ml for men. The formula of Keys and Brozek (1953) was used to determine body fat which was 19.9% for the women and 11.5% for men. The values obtained in this study were considerably lower than relative body fat determined for American men and women (Brozek et al., 1953; Young et al., 1961). Brozek and Young found percent body fat in men 14% and 12.1% respectively.

Durnin and Womersley (1974) measured total body density by underwater weighing on two hundred and nine males and two hundred and seventy-two females ages from sixteen to seventy-two years. Body fat was calculated using the equation of Siri (1956), although no significant difference arises from the use of the equations of Brozek, Grande, Anderson and Keys (1963). Mean body density for men, whose age was 20-29, was 1.064 ± 0.016 gm/ml and percent body fat was 15% ± 7.0

Potassium-40

In humans, potassium-40 is a naturally occurring radioactive nuclide. Since all potassium contains a constant proportion of ^{40}K, total body potassium can be calculated from ^{40}K measurements. Assuming that the potassium content of the lean body mass is constant, it is possible to estimate the fat content in man from a measurement of potassium-40 activity (Forbes and Lewis, 1956).

Potassium measurements on 1590 males and females ranging in age from one year to seventy-nine years of age were carried out by Anderson and Langham (1959). Potassium concentration in both males and females increased from the first year of life, peaked at age eight or nine and then declined sharply. The potassium concentration in males showed another sharp increase at age fourteen which peaked again at age sixteen. In constrast, in females the potassium concentration continued to decline rapidly until the age sixteen at which time the characteristic potassium content of the adult female was acquired. A consistent and parallel decrease in the concentration of potassium is shown in both sexes during adult life.

Fifty subjects (42 males and 8 females) were measured for total body potassium in an attempt to correlate estimates of body fat from potassium-40 with estimates of body fat from skinfold thicknesses and weight/height ratios (Forbes et al., 1960). Males ranged in age from eleven to forty-four years of age and females ranged in age from seven to twenty-three years of age. The range of potassium content in subjects was 35 to 58 mEq/kg in males and 23 to 52 mEq/kg in females. Fat content was calculated as the difference between total body weight and the lean body mass, based on a potassium content of 68.1 mEq/kg for the lean body mass. Relative body fat was calculated as 16 to 48% in men and 24 to 67% in females. Percent fat was correlated with average skinfold thickness (r = .80) and with weight/height ratio (r = .56) for the males.

Behnke and Wilmore (1974), reported correlations of .93 for young boys and .74 for girls between lean body weights calculated from ^{40}K analyses and lean weights calculated from body density. Myre and Kessler (1966) reported that of one hundred subjects tested eighty-two had higher fat values by the ^{40}K method than the values developed from actual density measurements (r = .87). Murphy, Lohman, Oscai, and Pollock (1969) conducted similar studies but found almost similar fat values derived from ^{40}K and body density (r = .88).

There is limited evidence that endurance exercise prior to ^{40}K analysis causes a transitory increase in that value, and concomitant errors in the percent body fat calculations (Londeree and Forkner, 1978).

Body Density vs. Potassium-40

Myhre and Kessler (1966) compared percent fat estimated from body density and from body potassium measurements on one hundred males ranging from fifteen to eighty-seven years of age. Results obtained from the two methods agreed well with a correlation of 0.80 but the potassium-40 method gave greater mean values for fatness than those obtained from underwater weighing indicating the possibility of a systematic error in one or both methods. The estimates of body fat obtained from body density ranged from 4.1 to 36.3% with a mean of 18.8%. Body fat estimated from potassium-40 measurements ranged from 3.7 to 49.9% with a mean of 22%. In eighty-two out of one hundred cases, values for relative body fat were higher for the potassium-40 method than those obtained by body density.

Body composition was estimated in terms of quantities of water, fat, protein, mineral and total body density in ninety-seven subjects by Krzywicki and Consolazio (1968). Body density was computed from body volume measured by direct water displacement techniques of Allen et al., (1956) and total body potassium was determined by a whole body NaI crystal counter. Percent fat by body density averaged 14.4% ± 2.9 in the seventeen year olds to 24.4% ± 1.3 in the nineteen year olds and 37.1% ± 5.1 for the fifty plus age group. Percent fat by body potassium was not given. The correlation between body density and body potassium in grams/kg of body weight was 0.73.

Total Body Water

Total body water has been carefully calculated as 78.4% of the body weight less its bone mineral (Allen and Krzywicki, 1961; Behnke and Siri, 1958). Critical analyses of cadaver material has determined the biological constant for water in the lean body tissue at 73.2% (Mitchell et al., 1945; Forbes et al., 1956).

Faller, Bond, Petty and Pascale (1955) described a relatively simple procedure for oral ingestion of deuterium oxide and subsequent analysis of urine for determination of total body water. From total body water lean body weight can be easily calculated given the constant concentration of water in lean tissue.

Behnke and Wilmore (1974) reported data which compared lean body weights calculated from total body water and direct density measurements. There were very large differences which probably reflected a variable state of hydration (S.E. = 8.2%). Osserman, Pitts, Welham and Behnke (1954) reported a much higher relationship between total body water and direct density data (r = .90, S.E. = 3.5%).

Somatology

Sheldon and colleagues are responsible for somatotyping's wide application in physical anthropology and various clinical disciplines. The Sheldon system basically involves the careful posingwith anterior, posterior and lateral photographing of the subject. Two indices are calculated from the height-weight history and the photographic analyses; the ponderal index and the trunk index from which an individual somatotype is developed, utilizing standardized tables. Sheldon, Dupertis, and McDermott (1954) published a photo description of the endomorph-mesomorph-ectomorph somatotypical interrelationships titled the Atlas of Man. This atlas provides a fairly objective reference for the use of the Sheldon somatotype scale.

Hertzberg et al., (1963) studied the physical types of Turkish, Greek and Italian military personnel by taking somatotype photographs of every subject and analysing them according to the method devised by Sheldon et al, (1954). They reported that 45.6% of the Turkish subjects were classified as mesomorphs (3-5-4 or 2^2-4^2-3^2) as compared to only 24.8% of the Greek and 34.8% of the Italian subjects.

Heath (1963) described some of the major problems in the use of somatotyping with large numbers of subjects, particularly with regards to the arbitrary scale of 0-7. Carter (1968) teamed with Heath in the development of an alternative somatotype system.

Tanner published in 1964 a detailed somatotype analysis of one hundred thirty-seven male track and field athletes who participated in the Rome Olympic games. The somatograms for this population were strongly skewed on the mesomorphic and ectomorphic scales, as compared with male college students of about the same age, who showed a very smooth trilateral geometric distribution.

DeGaray, Levine and Carter (1974) did a similar analysis of the male and female athletes at the 1968 Mexico City Olympic games. Almost all of the athletes in the various sports competition, demonstrated a moderate to high mesomorphy rating.

Wilmore (1977) concluded from the various studies that an individual's somatotype changes very little during the lifespan. Minor changes in the proportional amounts of fat and muscle transpire as a result of diet and/or exercise. This inability to significantly modify the somatotype is apparently the result of strong genetic factors which regulate the body composition throughout life.

Radiogrammetry

X-ray visualization of the anatomical constituents would resolve some of the subjective problems associated with the use of external anthropometric measurements. The technique is, in fact, very valid for assessment of body composition changes associated with the growth process (Tanner, 1965; Maresh, 1966). It was not apparent from this review that the theoretical mathematical problems associated with prediction of total body fat on muscularity from isolated limb or trunk X-ray data have been resolved. Behnke and Wilmore (1974) recommended the application of Matiegka's skinfold principle (1921) for conversion of individual radiogrammetric fat widths to % fat as a function of body surface area.

Radiogrammetry is ultimately a much more critical measure of isolated subcutaneous fat than data obtained from the caliper skinfold technique (Hunt, 1961). Garn (1961) summarized the technical methodological problems involved in the applications of radiographic analysis of body composition. The technical advantages of the method must be weighed against the recognized clinical risks associated with cumulative radiation, although Garn (1957) postulated that the high kilovoltage required is minimized by the short exposure time (1/30 sec.).

Baker, Hunt and Sen (1958) reported upper arm fat as a total of the radiographically computed area as 18.5% in males and 45% in females.

Behnke and Wilmore (1974) described a specific laboratory method for the purpose of the measurement of localized anatomical subcutaneous fat. Its applicability would seem to be particularly appropriate in studies of training effect upon specific extremity tissue locales.

Gas Absorption

Certain inert gases are very fat soluable and thus it is possible to estimate body fat from their rate of absorption. Cyclopropane and krypton are the inert gases used for this purpose and Lesser and Zak (1963) reported a mean difference of .83 kg of absolute fat in human subjects when calculated from inert gas absorption and total body water.

Underwater (Hydrostatic) Weighing

One of the most precise measurements of body composition is obtained by measuring body density by means of underwater weighing. The technique is based upon the Archimedean principle that loss of weight in water is equivalent to the body volume. Density is then $\frac{\text{Body Weight Air}}{\text{Body Weight Air - Body Weight Water}}$. Once the body density or specific gravity is calculated from the underwater weighing method it is relatively easy to use basic equations for determining % body fat (Siri, 1956).

Essentially, the subject, who is in a post absorptive state is suspended underwater from a carefully calibrated scale on a seat or sling. Multiple trials of underwater weight following maximal forced expiration are determined from the scale reading and corrections made for their weight, water temperature, residual lung volume and the estimated volume of gastrointestinal gas. Goldman and Buskirk (1961) and Buskirk (1961) published good reviews of the laboratory technique. Katch, Michael, and Horvath (1967) described a portable wooden shell for use in a shallow swimming pool facility from which a scale can be hung and hydrostatic density measurements obtained. Although this type of measurement is not as accurate as that obtained under more standardized laboratory conditions, it allows for the expedient testing of a larger number of subjects in a field setting.

Determination of a residual lung volume for the final body density calculations may be measured directly, estimated from vital capacity or by use of an assumed average residual volume. There is very close agreement on the body density values calculated by all three methods (r = .875 - .948). The differences in the mean densities for 69 males and 128 females calculated from the actual, estimated and assumed average residual volumes were less than .001 gm/cc (Wilmore, 1969).

Katch (1971) demonstrated with sixty-two young men who underwent physical tranining that the me-sured changes in body density were apparently more reflective of changes in residual lung volume than changes in underwater weight. Therefore, he cautioned against the use of assumed average residual lung volumes in longitudinal studies of body composition.

Behnke and Wilmore (1974) recommended that when the same subjects are followed for a long period of time it is best to do direct measurement of the residual volume while the subject is submerged by means of nitrogen, helium or oxygen dilution.

Thomas, Etheridge, Londeree and Shannon (1979) recommended the use of functional residual capacity rather than residual volume when clinical spirometry is utilized during underwater weighing. They reported no significant differences in body densities calculated from function residual or residual volume values.

The correction of volume of intestinal gas in the calculations of underwater densitometry is not as critical as the residual lung volume because of the much smaller volume of gas and therefore minimal buoyancy effect. Bedell, Marshall, Debois, and Harris (1956) used a total body plethysmograph and an intragastric balloon with a large number of clinical patients as well as normal subjects. The range of the volume intestinal gas reported was 0-500 ml, average 115 ml, with a 50-300 ml variability within subjects. Buskirk (1961) provided further interpretation on the matter and recognizing the slight reducing effect of water pressure on volume of intestinal gas suggested that Bedell et al.'s average figure of 115 ml be reduced to 100 ml.

The basic hydrostatic equation for density, correcting for the residual volume and volume of intestinal gas factors is (Behnke and Wilmore, 1974):

$$\text{Density (D)} = \frac{\text{Weight-Air}}{\dfrac{\text{Weight-Air} - \text{Weight Water}}{\text{Density Water}} - (\text{Residual Volume} + 100\text{ ml})}$$

Several equations have been derived for the determination of percent body fat from hydrostatically or water displacement acquired density data. These derivations are based upon the density of fat (.907 approximately) and lean body tissue (1.100 approximately) (Wilmore, 1977).

Equations were developed by Siri (1956), Rathburn and Pace (1945), Brozek, Grande, Anderson and Keys (1963). Wilmore and Behnke (1968) adequately demonstrated that the small differences in the constants used in these different equations resulted in very high intercorrelations among the percent body fat values calculated by the three methods ($r = .995 - .999$).

Thomas, Etheridge, Londeree and Shannon (1979) had trained distance runners complete a 10-12 mile run with pre and post hydrostatic weighing. The average dry weight loss in the eight subjects was 1.3 kg. Percent body fat decreased from 10.1% to 9.2% in the pre-post run hydrostatic measurements. The authors concluded that the observed changes were due to dehydration caused by sweat loss, the net effect of which is to increase body density and thereby decrease percent body fat values.

Girandola, Wiswell and Romero (1977) demonstrated that dehydration decreased percent body fat, whereas fluid ingestion increased this value. They suggested that standards need to be established for both exercise and state of hydration for a specified time period before subjects undergo hydrostatic weighing.

Water Displacement (Body Volumeter)

This technique is of Archimedean origin also, insofar as the volume of water displaced by an object in water is equal to the volume of the object. The subject exhales maximally and is then submerged in a specialized tank with a very accurately calibrated burette which measures the increase in water volume that occurs.

Allen, Krzywicki, Worth and Nims (1960) reported on the intricacies of the system and a standard error of ± 1.04 kg fat. It is less precise than either the underwater weighing or the helium dilution method of volumetric analysis (Consolazio, Johnson and Pecora, 1963).

Borzek and Wilmore (1974) described how the technique may be adapted to independently measure trunk or limb volumes.

The basic equation for the calculation of density from water displacement measurements is (Brozek and Wilmore, 1974):

$$D = \frac{\text{W-Air}}{\frac{V}{\text{D Water}} - (\text{RV} + 100\ \text{ml})}$$

Helium Dilution

Attempts to use the air displacement method of measuring body volumes were reported by Wedgewood and Newman (1953) and Walser and

Stein (1953). Siri (1956) and Siri (1961) refined the technique which has the distinct advantage of minimal subject discomfort, an important consideration when working in a clinical situation or with subjects who have a perverse fear of water submersion.

Siri (1956) described in detail the apparatus for this procedure. The subject was placed in a 400 liter chamber which had a connecting helium metering system with a volume of about 15 liters. A known volume of gas was introduced into the chamber and at equilabration the density of the gas used to calculate the volume of the subject. Since the chamber was a constant volume, the larger the subject, the higher the concentration of helium. Thermal conductivity transducer systems were used to detect the concentration of helium.

Siri (1961) has estimated that the helium sensor system must be accurate to about .001% in order to provide a standard error no greater than ± 1 liter in the subject volume calculation.

Behnke and Wilmore (1974) outlined the equation for calculating body volume based upon this form of air displacement and stated that the formulation does not require a correction for residual volume since the concentration of helium air in the lungs is equal to that in the chamber.

Height-Weight-Composition Interrelationships

The first height-weight standards of the U.S. population were published by the Association of Life Insurance Medical Directors and the Actuarial Society of America in 1912 (Medico-Actuarial Investigations, 1912). These data have been updated in various source references many times and involve essentially averaging the weights of men and women of a given age and height. More recent reports of this type provide average weight in pounds for each inch of height (Brozek, 1961). Other weight standards were developed which took into account differences in skeletal frame (Brozek, 1956) utilizing several bony diameters and leg length (iliocristal height). These additional parameters permitted the development of more accurate equations for predicting standard weight.

Welham and Behnke (1942) were among the first investigators to spell out the inadequacy of traditional weight standards. Of twenty-five professional football players, seventeen were classified unfit for military service because of presumed overweight. Of these seventeen players, eleven were shown through laboratory evaluations to be very low level fat. Their "extra poundage" was therefore lean mass, rather than fat tissue.

Wamsley and Roberts (1963) underscored the inadequacy of military weight standards. They compared the actual body composition of fifty-one Air Force male personnel against the service standard for obesity (115% of standard weight). Fifteen men who were not classified overweight were in fact more than 20% body fat. Six persons who were listed as overweight were less than 20% body fat. Keys and Brozek (1953) and Kandel (1969) also developed other documentation to negate the validity of using standard weight tables which do not incorporate more intrinsic body composition criteria.

Behnke, Guttentag and Brodsky (1959) and Behnke (1961) demonstrated the valid prediction of body weight from height and a combination of eleven circumferences (S.E. = 2%, $r = .98$). Later, Behnke and Wilmore (1974) reported that with the refined methodology, they obtained a correlation of .976 between predicted and actual body weight (women, r =.975). These basic geometric extrapolations which were based upon mathematical models for reference man and woman, established the theoretical framework for qualitative predictions of body composition from simple anthropometric measurements (Holland, 1970).

Perimetric (Girth) and Bimetric (Frame Size)

The frequently used standard, the age-height-weight table, is of limited value in evaluating physique, for it is now established that overweight and overfat are not the same thing. This point is clearly illustrated with athletes who are muscular and in excess of some average weight for their age and height, but otherwise lean in terms of body composition. For such people, a weight loss program is unnecessary and may even be harmful to sports performance. On the other hand, it is possible to be "average" for body weight yet still possess undesirable excess of body fat. In this situation, a weight loss or body composition modification program may be desirable (McArdle, Katch, and Katch, 1981).

In 1956, the Committee on Nutritional Anthropometry recommended bimetric methods of assessing the lateral dimensions of the skeletal frame; bicristal diameter, which is the distance between the most lateral margins of the acromial processes of the scapulae.

Brozek (1956) combined the bicristal-biacromial diameters with the upper arm girth (as a relative indicator of muscular development), biepicondylar diameter of humerus, cristal height and height to develop equations for the prediction of body weight in 238 Minneapolis firemen (25-63 years). The combined measures of the bony muscular development and of age accounted for about 60% of the interindividual variance in body weight. (R^2 = .596 for seven independent variables, and R^2 = .592 for five predictors excluding cristal height and biepicondylar diameter of humerus). By comparison, the coefficient for determination for height, r^2 = .227. For the corrected upper arm circumference, which is the best single predictor of weight, r = .348. Clearly, the gain from combining the measurements, together with age, was sizeable and the predicted weight was a good deal more precise and biologically meaningful standard than could be obtained from the traditional height-weight tables. The standards developed for this population were used to estimate the amounts of addipose tissue by which an individual differed from the average man of given skeletomuscular proportions.

Behnke, Guttentag and Brodsky (1959) stated that the sum of eleven circumferences (shoulder, chest, abdomen, buttocks, thighs, biceps, forearm, wrist, knee, calf and ankle) divided by a constant (k = 300), may be converted into a quotient (d) which serves as a geometrical dimension, so that

$$d^2 x h = w$$

where h = stature and w = weight

In turn, it is possible to assess body build quantitatively and to relate anatomical divisions of the body rather than body weight to physiologic parameters (S.E. = 2%, r = .98).

There are a wide variety of other circumferential and diameter morphological techniques. Behnke (1961) described the field methods of measuring eight bony diameters and formulated an equation for predicting lean body weight.

Van Dobeln (1961) developed a predictive equation for height, radio ulnar breadth (wrist diameter), and femoral condylar breadth (knee diameter) to estimate body density.

Perimetric (girth) measures involve the uses of a linen or flexible steel tape for measuring around a body segment. When girth of the limb is obtained and corrected for skinfold and subcutaneous fat, it is a good characterization of musculature (Brozek, 1961).

Taylor and Behnke (1961) divided body weight into two segments, trunk (A) and extremeties (B). The first group included the average of two abdominal circumferences while the second included circumferences of the biceps and the calf. An approximation of body fat can be made based on the assumption that in a given male individual when w (A) = w (B), fat would equal 19% of body weight. In obese men, the difference between the two would be excess fat and in muscular men it would be lean tissue. Lean body weight was estimated on twenty male subjects from skeletal diameters, total body water and whole body density as a basis of comparison. It was found that in comparing muscular and obese men from circumferences, a functional estimate of body composition can be made which underestimates body fat in almost all cases as opposed to measurements from body density.

Katch and McArdle (1973) studied 53 men and 69 women using thirteen circumferences and eight body diameters to determine body composition. In the men, the best combination of circumferences to predict body density included the arm, abdomen and forearm. In the women, the arm, abdomen, forearm and thigh girth predicted body density the best. When body diameters were used to predict body density, the multiple correlation based on all eight diameters did not exceed .55 for either men or women. Circumferences alone provided the multiple correlation of .83 in men and .80 in women.

Bharadwaj, Singh and Malholta (1973) compared the body circumferences of high-altitude natives with those of sea-level residents. The studies were also conducted both at high altitude and sea level situations. The sea-level residents were 30 young and healthy Indian subjects of the state of Tamil Nada, India. The high-altitude residents were 45 young and healthy Indian local inhabitants of high altitude (3962 m. above sea level). The last group was 17 young and healthy Indian soldiers, who were continuously exposed to an altitude of 3962 m. for ten months. The results showed that the abdominal circumference and chest circumference of the high-altitude inhabitants were greater than those of the sea-level residents (96.57 cm >48.14 cm and 34.41 cm >34.33 cm respectively). The third group had four weeks of acclimatization and 10 months continuous stay at the altitude of 3962 m. The means of the chest circumference and the knee circumference of the subjects after four weeks of acclimatization were lesser than after 10 months of continuous stay.

Behnke and Wilmore (1974) concluded that biacromial, bitrochanteric (distance between the most lateral projections of the greater trochanters) wrist and ankle diameters combined provided the most valid lean body weight values. Such estimates of lean body weight from frame size correlate well with hydrostatically determined lean body weight (r = .879 - .924).

Katch and McArdle (1977) outlined the best circumferential measures to be chosen for different age and sex groups from six basic girths; upper arm, forearm, abdomen, buttocks, thigh and calf and provided tables of constant values for young and older men and women in the estimation of percent body fat. They reported that predicted fat values obtained were within 2.5 - 4.0% of the values developed by water displacement or hydrostatic weighing. They also suggest that equations for the prediction of percent body fat from circumferential measures are undoubtedly population specific, and therefore, separate formulations are needed for a group who vary significantly in fitness and/or body composition.

Skinfold

Matiegka (1921) first proposed that body fat could be computed from the product of surface area, six skinfold thicknesses and a predictive constant.

Because of the extensive laboratory equipment and time required to conduct underwater (hydrostatic) weighing or water displacement determination of body density the applicability of a convenient field method such as skinfold measurements was obvious. T. K. Cureton (1947) is credited with much of the early detailed work on skinfold evaluations of athletic populations. Brozek and Keys (1953) provided an early comprehensive review of the skinfold measuring techniques. Edwards (1950) published the first classical anthropometric analysis of human subcutaneous fat derived from skinfold measurements. He described 53 anatomical sites which would give excellent representation of the total body subcutaneous fat. The average skinfold total for men (20 - 35 years) was 412 mm. It was clearly obvious that fewer anatomical sites would have to be identified for the accurate prediction of body fat if the skinfold method was to have broad applicability.

The question of which skinfold sites are most representative of the approximately 50% of body fat found in the subcutaneous depots has been an continues to be controversial. Brozek and Keys (1951) were the first to use the relationship between skinfold thickness and body density for assessing fat content. The three skinfolds chosen were abdominal, chest and triceps, which later proved not to be ideal, and thus their formula was not very widely used (Durnin and Rahman, 1967).

Keys and colleagues (1956) suggested that the triceps and subscapular skinfold sites were the best indicators of total body fatness. Pett and Ogilvie (1956) reported a Canadian anthropometric survey of 22,000 persons and supported the triceps skinfold as the single best predictor of body fat-leanness. The U.S. Committee on Nutritional Anthropometry, in 1956, endorsed the use of triceps and subscapular skinfold sites as the best suited for general survey purposes.

Allen et al., (1956) compared the sum of ten skinfolds which proved to be very widely used for clinical studies in twenty-nine women with the percent body fat measured by the hydrostatic weighing technique. His predictive equation was based upon the assumption that more measurements taken from various anatomical regions would provide more valid estimates than one or two skinfold values. He reported that total adiposity in both sexes can be predicted from skinfold measurements with a standard deviation of 2.02 kg. Also, fat people have approximately two-thirds of excess fat located just beneath the skin while lean people have less than one-third excess fat located subcutaneously. He also very significantly described the curvilinear relationship between subcutaneous and internal body fat.

Newman (1955) studied the skinfold measurements of 2,017 American-born white and 361 American black males who were measured shortly after induction into the United States Army and before the start of basic training. The subjects were 17-28 years old. The mean skinfolds at the five sites (chest, arm, back, knee and abdomen) for whites ranged from 10 mm on the chest to 15 mm on the knee and for blacks ranged from 6.5 on the chest to 12.9 mm on the knee. A racial constrast emphasized the leanness of the young black male and his distinctive deficiency of subcutaneous fat over the pectrol and tricep regions. Geographic groupings of the men indicated a regional difference between Northerners and Southerners for both whites and blacks. In regional comparisons of the white subjects, the South Atlantic region had the lowest mean skinfolds (chest lowest with 9.3 mm and knee highest with 14.1 mm) and East North Central region had the highest mean skinfolds (chest lowest with 11.4 mm and knee highest with 16.2 mm).

Pascale et al., (1956) studied 88 soldiers (17-25 year old males) to determine which sites for skinfold thickness measurements on the chest and abdomen have the greatest power in predicting body density. The results showed that the chest site in the mid-axillary line at the level of xyphoid (r = .828) was superior to the site immediately adjacent to the nipple (r = .825) and to the site at the mid-point between the nipple and the anterior axillary fold. On the abdomen, the site adjacent to the umbilicus proved to have the highest r value (r = .77). The prediction equation developed used only the skinfold thicknesses taken at the chest in the mid-axillary line at the level of the xyphoid, at the chest in the juxta-nipple position, and on the dorsum of the arm at the mid-point between the tip of the acromion and the tip of the olecranon. The multiple regression coefficient, R, for the equation was .85 and the standard error of estimate was .0065 body density units.

Parizkova (1961) determined skinfold thicknesses at ten sites and body density measures on 123 boys and 118 girls in two age groups, nine to twelve years of age and thirteen to sixteen years of age. In boys, skinfold thicknesses on the arms, below the chin, and on the cheek correlated best with body density. In girls, the highest correlation with body density was found in skinfolds of the trunk, on the back and on the side. For the prediction of body density, all ten skinfolds gave the highest correlation.

Sloan, Burt and Blyth (1962) developed an equation very similar to that of Brozek and Keys (1951) for estimating body density from abdominal and triceps skinfold of young females. Sloan (1967) published a similar equation for young men incorporating anterior thigh and scapular skinfolds only. Refinement of these methodologies by 1970 resulted in Sloan and Weir deriving separate formulas for young men (18 - 26 years) using thigh and scapular skinfolds, and women (17 - 25 years) using iliac and tricep skinfolds.

Nagamine and Suzuki (1964), between 1950 and 1958, studied the body composition for the characterization of the nutritional status of young Japanese men and women. They measured ninety-six 18 - 27 year old males and one hundred and twelve, 18 - 27 year old, healthy college students in Tokyo. In this study the skinfold thicknesses at six sites ranged from 8.0 mm on the arm to 10.9 mm on the back for men. The correlations between body density and skinfolds were highest in the abdominal region at the mid-axillary line (r = .80) for men and subscapular region (r = .70) for women. They also reported that the skinfolds on Japanese were less than those on Americans in both men and women (Brozek and Keys, 1951; Pascale et al., 1956; Newman, 1956; Skerly et al., 1953; Young et al., 1961) and this racial difference was greater in men than in women.

Montoye et al., (1965) in their study of a total community examined 8,641 person (88% of the Tecumseh, Michigan community), between the years of 1959-1960. They reported percentile tables for subscapular and tricep skinfold measurements of 2,566 males and 2,632 females in 17 age groups ranging from 0 to 80+ years. They compared the median scores of tricep and subscapular skinfold values for various age groups of their study and the Canadian study of Pett and Ogilvie (1956) and reported that in both studies the tricep skinfold measurements showed little change with age in male subjects but increased until the age of sixty in female subjects. The median subscapular skinfolds increased with age in both male and female subjects. In the Canadian survey the median subscapular skinfolds at each age was lower in both sexes.

Durnin and Rahman (1967) compared hydrostatically determined fat values with skinfold estimates in 105 young adult men and women, and 86 adolescent boys and girls. The skinfold estimates were based upon biceps, triceps, subscapular and suprailiac measures. They reported the following negative correlations between hydrostatically determined density measurements and the cumulative total of the four skinfold thicknesses: adult females r = .788, adult males r = .835, girls r = .778, boys r = .760. Separate equations were derived for all four populations to differentiate the age-group and sex differences.

Durnin and Womersley (1974) updated their equations for males (N = 209) and females (N = 272) ages from 16 to 72 years derived from the original four skinfold measurements (biceps, triceps, subscapular, and iliac). Practical tables were developed from which percent body fat can be read directly from the cumulative value of the four skinfolds of different sexes (male and female) and different age groups (16 - 29; 30 - 39; 40 - 49; 50+).

Garn, et al., (1977) reported their study based upon four fatfold measurements (subscapular, tricep, abdominal, and iliac) and two education levels (8 years or less and over 12 years) on 4,936 adult participants in the Tecumseh, Michigan project of the University of Michigan School of Public Health (Napier, et al., 1970) that were taken during examination round 2, between 1962 and 1965. Among males with more than 12 years of schooling, the average thickness of 4 fatfolds was 10% greater, amounting to about 2 kg of total fat, than those with 8 years or less education. In females, however, the opposite trend was observed, those in the higher educational group averaging 20% thinner fatfolds, or about 5.5 kg total fat, than females in the lower educational group.

Mueller and Stallones (1981) studied the subcutaneous fat site choice by using the data of 1,525 Colombian subjects (Mueller and Titcomb, 1977) and 1,204 American subjects derived randomly (stratified-all ages equally represented) from the United States Health Examination Survey (Johnston, et al., 1974). The ages of all of the subjects ranged from 7 to 80 years. In both groups, trunk and tricep sites had the highest correlations (r = .80 - .96) with the first principal component (fatness), and the medial calf had the lowest (r = .76 - .94). Also in the eight sex/race/age groups, the medial calf skinfold had the greatest correlation with the second component (extremity-trunk). However, the magnitude of this correlation was low (r = .29 - .59). When the skinfold sites were summed pairwise, any combination of two skinfolds gave correlations in excess of .9 with the first component (fatness) and correlations close to zero with the second component in both data sets. Evidently any two sites selected from the general areas of the body considered here were sufficient for the study of human fatness. Most of the patterning indices (difference between two sites) produced near zero correlations with the first component (fatness) (r = -.13 to .15). The pattern index which had highest correlations with the second (extremity-trunk) component was a combination of the two sites which had the highest positive and highest negative correlations individually with this component. In all age/sex/race groups this involved the medial calf in concert with one trunk site (suprailiac for Colombians and subscapular for Americans). Therefore, medial calf and one trunk site were the minimum two sites appropriate for studies involving fat patterning.

Crank and Roche (1982) analyzed the data recorded in the First Health and Nutrition Examination Survey conducted by the National Center for Health and Statistics (n = 14.118; age = 6 - 50.9 years). They presented the race and sex specific reference data for tricep and subscapular skinfold measures and reported that the subscapular skinfold percentiles increased much more markedly in the upper than lower percentiles until early adulthood in both black and white males. Black and white males had similar values for corresponding percentiles at most ages except that the 95th percentile was higher in blacks after

17 years. Tricep values for 50th through 95th for males increased moderately from 6 through 17 years after which they decreased till the end of adolescence. The percentiles for females exceeded those for males of the same racial group at all ages. They also reported that the racial differences noted between the sets of reference data for triceps and subscapular were similar to those reported in studies by Newman (1955), Steinkamp et al., (1965), Harsha et al., (1978), Garn and Clark (1976), Johnson and Malina (1966), Malina (1969), Malina (1971), Malina (1972), Malina et al., (1974), Johnston et al., (1974), Ten-State Nutrition Survey (1972), and Gordon and Miller (1964).

Combinations of Skinfold, Perimetric (Girth), and Bimetric (Frame Size)

Damon and Goldman (1964) compared percent body fat from ten anthropometric formulas with those determined by densitometry in 13 athletic young men. The closest predictions of densitometrically determined fat were obtained from the two standard skinfold sites, triceps and subscapular, by the equations of Pascale et al., (1956) or Brozek and Keys (1951). The difference between predicted and densitometric fat percentages averaged ±2.0% for the Pascale formula. Almost as good was Brozek's (1955) formula based on the endormorphic (round, "soft") component of the somatotype. Predictions from formulas of Matiegka (1921), Dupertuis et al., (1951), Hunt (1958), Chinn and Allen (1960), and Behnke et al., (1959) were unsatisfactory. Individual subjects whose fat was predicted poorly were at the extremes of age, height, and weight for the group. Ease of prediction varied with the difference between endomorphy and mesomorphy (squareness, muscularity) and inversely with their sum.

Wilmore and Behnke (1969 and 1970) compared body composition values derived from hydrostatic weighing with that obtained from a large number of skinfolds, diameters and circumferences in 133 young males and 128 young females. The results of their comprehensive analyses showed that body density and lean body weight can be predicted fairly accurately from skinfold, perimetric, bimetric or selected combinations of these and correlations ranged between .77 and .80.

Katch and McArdle (1973), in their study of 53 men and 69 women, reported that when skinfolds and circumferences were used alone to determine body fat, it did not change (same multiple r = .83) for men, but for women correlation was lower (r = .77) when skinfolds were used than when circumferences were used (r = .80).

Wilmore, Girandola and Moody (1970) tested the accuracy of combined skinfold-girth equations developed by ten different investigators. They were interested in whether such equations could adequately predict actual pre-post training changes in body composition as measured by hydrostatic weighing. The low correlation reported for the body density predictions suggested that direct densitometric measurement is the preferred approach for identification of qualitative changes in the total body composition that may be associated with an exercise training regimen.

Sinning (1978) conducted a comparative analysis of equation developed by five different investigators that utilized various diameters, circumferences and skinfolds to predict lean body weight. His comparisons of the predicted lean body weights with measures obtained by underwater weighing resulted in good correlations (r range = .91 - .95). All of the five equations, however, underestimated the true lean body weight (range of error 1.13 - 3.88 kg). He reported that the thigh circumferential equation developed by Weltman and Katch (1975) grossly underestimated the lean body weight of college female gymnasts and as previously reported by Sinning, Wilensky and Meyers (1976) that anthropometrically derived equations for predicting minimum weight of high school wrestlers (Tcheng and Tipton, 1973) produced estimation errors of approximately 3%, such results tend to confirm the population specifity thesis for the use of such equations.

Jackson, Pollock, and Gettman (1978) compared the inter-tester reliability of three technicians in selected skinfold, circumference measurements and percent fat estimates. The skinfolds selected for study included chest, axillary, triceps, subscapular, abdominal, thigh and iliac. The four circumferential measures were abdominal, gluteal, flexed upper arm and forearm. The percent fat was estimated using four anthropometric equations developed for males (Jackson and Pollock, 1977). Of the seven skinfold fat measures, significant inter-tester differences were found at four sites (chest, subscapular, iliac, and thigh). The largest difference among the skinfold percent fat estimates was only .3% (S.E. -1% fat). A significant mean difference among testers was found with three of the four circumference measurements, but once again the largest average percent fat estimate differences among testers was only 1.3% fat. These findings supported the use of anthropometric field methodology with technically well trained personnel.

Sinning (1980) reviewed the problems associated with anthropometric estimates of body composition in different populations. Based upon extensive experience and a thorough review of the literature he concluded that anthropometric data alone were not very good predictors, particularly for specialized athletic populations. He recommended that anthropometric estimates of body composition should be used with very circumscribed populations, and in tandem with other data such as height-weight tables, body weight history, etc. for arriving at a generalized profile of the individual at a given point in time.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to develop an equation to predict percent body fat of 18 - 25 year old Turkish males through skinfold testing by using underwater weighing measurements as the criterion, and to compare the new equation with various equations already used around the world. It was also intended to compare anthropometric measurements of the following groups:

1) University students of seven geographical regions of Turkey;
2) urban non-students from the city of Ankara, Turkey;
3) rural non-students from the villages surrounding the city of Ankara, Turkey;
4) males of other countries around the world where data was available in the literature for similar age group subjects.

Subjects

The subjects of this study were three groups of 18 - 25 year old Turkish males.

The first group consisted of eighty-four university students who were residing in the city of Ankara at the time of testing (July - August, 1982). This group was randomly selected and stratified, representing the total Turkish population of seven geographical regional sub-groups (see Appendix B). The numbers of the subjects in each sub-group did not represent the same proportion of the regions' populations to the total Turkish population. Instead, the representation of the total population by these sub-groups is shown in Table I.

TABLE I

REPRESENTATION OF THE TOTAL TURKISH POPULATION IN SEVEN "GEOGRAPHICAL REGION" SUB-GROUPS

Group 1

Region	Population	% of Total Pop.	No. of Subjects
1. Black Sea	7,489,299	17	16
2. Marmara	9,435,210	21	17
3. Egean	5,954,504	13	13
4. Mediterranean	5,257,808	12	11
5. Central Anatolia	8,261,527	18	13
6. East Anatolia	4,770,981	11	9
7. South East Anatolia	3,567,627	8	5
TOTALS	44,736,956	100	84

Source: Census, 1981

The second group consisted of 50 urban Turkish males from the city of Ankara with education levels below high school graduation.

In the third group, there were also 50 Turkish male subjects with an education level below high school graduation. However, they were from the small towns and villages surround the city of Ankara representing the rural population. The distribution of the subjects in group three was not systematic and shown in Table II.

TABLE II

REPRESENTATION OF RURAL NON-STUDENT SUBJECTS

Group 3

Name of The Area	Number of The Subjects
1. Polatli	9
2. Kalecik	3
3. Kirsehir	7
4. Kizilcihamam	14
5. Kirikkale	3
6. Cubuk	2
7. Güdül	4
8. Cankiri	2
9. Kazan	1
10. Sokullu	1
11. Beypazari	1
12. Sereflikochisar	1
13. Gölbasi	1
14. Bâlâ	1
TOTAL	50

As the testing crew visited each testing site, they approached the prospects and asked them about their age, education level and area of living. After. Their eligibility for this study was confirmed, they were briefed about the purpose of this study and were asked to volunteer to be a subject.

The means and standard deviations for the anthropometric measurements of people from other countries were taken from other published studies.

General Procedures

Tests for this study were performed in the city of Ankara and in the towns of Polatli and Kizilcihamam, both of which were located in the province of Ankara. Testing sites were located at various places such as the campus of Middle-East Technical University, the campus of Turkish Military Sport School in Ankara, facilities of the Ministry of Youth and Sport Youth and Culture Centers located in two different sections of Ankara, local youth clubs, cafe shops, private business offices, and subjects' homes.

The testing crew consisted of the investigator who performed all the skinfold measurements and underwater weighing, and one or two college students who helped with the recording of personal data and results of the tests. The investigator was trained by Dr. A. B. Harrison on taking the skinfold and underwater weight measurements for the purpose of insuring the validity and reliability.

Test Administration

All of the subjects were evaluated in the following sequence:

A. The collection of personal information.
B. Height and weight measurements.
C. Skinfold measurements.

In addition to the evaluation above, underwater weighing, was given to the subjects of group one (university student subjects).

Collection of Personal Information

The collection of personal information was done by interviewing each subject and recording the information on individual forms (see Appendix A).

The individual data form included the first and last name, age, geographical area of living, and weekly physical activity with its type and duration.

The individual data form included sections to record the results of weight-height measurements, skinfold measurements, and underwater weighing.

Weight and Height Measurements

Weight was taken on a lever scale weight machine. This measurement was taken while the subject was wearing nothing but shorts or a swimming suit.

Height was taken while the subject was barefooted or only wearing a pair of socks on his feet and wearing nothing on his head. Measurement was taken on a measuring scale fitted with a sliding head-piece that could be moved up or down to touch the top of the head. While the subjects were standing, wearing nothing on their feet, heels together, hands on hips with the body held in maximally erect position after a full inhalation, the height measurement was taken and recorded in centimeters to the nearest centimeter.

Skinfold Measurements

The skinfold measurements were taken on each subject at seven sites using the Lange Skinfold Caliper. Each site was located visually and marked so that consequent trials of measurements would be at the identical site. Each measurement was repeated until two identical readings were taken in a row. Skinfold measurements were taken on the right side of the body while the subject was standing erect with his arms by his sides as suggested by Brozek (Brozek, 1961).

The skinfold, including two layers of skin and subcutaneous fat was lifted from the underlying muscle between the ends of the thumb and index finger. The fold was held for the duration of the reading, applying the caliper approximately one centimeter from the fingers.

The locations of the skinfolds at the seven sites were:

1. Abdominal Skinfold - horizontal fold adjacent to and approximately five centimeters lateral from the umbilicus.

2. Tricep Skinfold - vertical fold on the posterior midline of the upper form (over tricep), halfway between the acromion and olecranon process.

3. Bicep Skinfold - vertical fold on the anterior midline of the upper arm (over bicep), halfway between the acromion and olecranon process.

4. Subscapular (Back) Skinfold - fold picked up just below the inferior angle of the right scapula and parallel to the tension lines of the skin.

5. Supra-Iliac Skinfold - in the mid-axillary line at the level of the crest of the ilium.

6. Thigh Skinfold - vertical fold in the midline of the front of the thigh halfway between the inguinal ligament and the top of the patella while the body weight shifted on to the left leg and right leg is relaxed but not lifted off the floor.

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

Underwater Weighings

The last phase of the testing procedure for the subjects who were in group one was under water weighing.

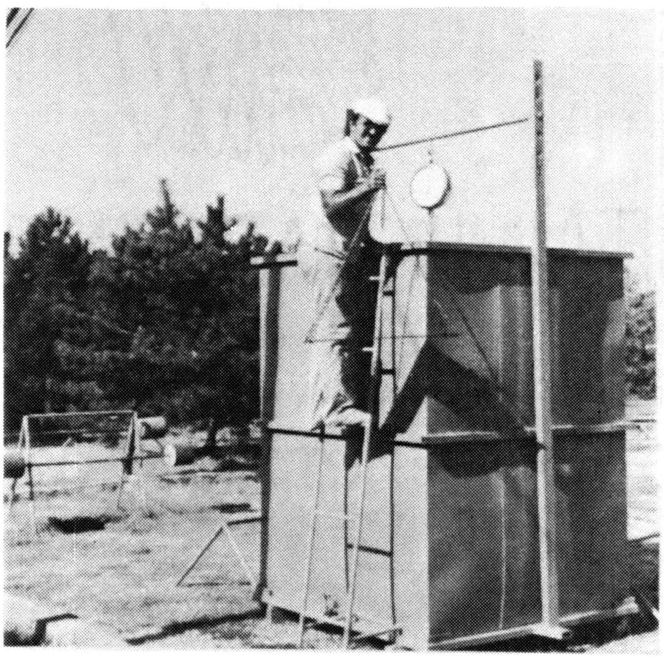

Figure 1. Water Tank

This test was conducted in the water tank (see Figure 1) built specifically for this study. The dimensions were 2.5 m. high, 2 m. wide, and 2 m. deep with two vertical bars extending above the middle of two opposing sites. The bars had holes in different levels so the connecting bar could be placed at different heights. The connecting bar had a hook in the middle supporting the Chatillan Scale. The seat was constructed from a metal plate and attached with a thin chain to the Chatillan scale in a swing-like seat fashion.

The height of water and seat was adjusted for each subject so they could stand up or sit on the seat and still have the water level at their chin, yet, they had no contact with the sides or bottom of the tank while in a sitting position. This gave the subjects a secure feeling which helped them perform the test procedures successfully.

The swing-like seat was weighed before each subject's testing and recorded. The water temperature was kept at about 35° C.

Subjects were at first briefed with the methods and procedures in the following sequence:

1) Get into the tank slowly.
2) Sit on the swing-like seat which is hooked to the Chatillan scale very slowly and stay calm because the Chatillan scale is very sensitive.
3. To submerge under the water totally, hold on to the seat and while pulling yourself down, curl your upper body and bend your head down and forward.
4. Before submerging underwater, blow all the air out and towards the end of this procedure start submerging. After totally submerging give a last attempt to blow more air out

then count to five before raising the head up and straightening the body to breath.

After these steps were reviewed with subjects they were allowed to practice 5-10 minutes in order to feel comfortable.

The subjects were weighed underwater a minimum of four times with the heaviest reading being obtained twice used as underwater weight. No more than ten readings were obtained for any subject.

For the calculation of body density and percent body fat the weight of the seat was subtracted from the underwater weight which gave the net underwater weight of the subject in pounds. Then, this value was divided by 2.2 to obtain its kilogram value. By using net underwater weight in the following formulas (Brozek et al., 1963), the predicted body density and percent body fat of the subjects were calculated.

1. Body Density:

$$D = \frac{BWa}{\frac{BWa - BW_W}{D_W} - (RV + C)}$$

where:

D = Body density

BW_a = Body weight in air in kilograms

BW_W = Net body weight in water in kilograms

D_W = Water density in gm/cc (assumed to be .996 at a water temperature of around 35° C)

RV = Residual volume

C = Constant (.1 liter)

2. Percent Body Fat

$$\% \text{ Body Fat} = \frac{4.57}{D} - 4.142$$

Since it has been noted that there are no statistically significant differences between the means for density, percent body fat or lean body weight calculated using the estimated or constant residual volume, the residual volume (estimated) of 1.3 liters was used as suggested for college age men by Willmore (1969).

Statistical Analysis of Data

Once the percent body fat of the group one subjects was calculated through underwater weighing method, the results were used as dependent variables in a multiple stepwise regression analysis while the skinfold measurements of the same subjects were used as independent variables. The multiple stepwise regression equation analysis produced a constant, regression value for each one of the seven skinfolds, and order of the correlations to the actual percent body fat value from high to low. From these results a regression equation was obtained to calculate predicted percent body fat including all seven skinfold measurements. Simultaneously, the residuals of the predicted percent body fat values to the true values were plotted on a graph to check and see if all of the values fell into the ± 2 standard deviation range. If there were one or more predicted percent body fat values that fell outside the range, the data giving those values would be deleted. By using the new set of data, a second multiple regression analysis would be done in order to strengthen the equation. Also, the shape of the distribution of the predicted percent body fat values on the graph was observed to see if any specific shape appeared to require correction of the sampling error.

By using the newly developed regression equation, a table and a nomogram were prepared to predict percent body fats without any mathematical calculations.

One-way analysis of variance (ANOVA) was used for each anthropometric measurement to determine if any significant differences existed between seven geographical region sub-groups and between the three groups. The .05 confidence level was selected in determining the significance of the differences. The variables for which analysis of variances were used to determine the significance of differences between the groups were:

1. Weekly exercise (hour)
2. Age (year)
3. Weight (kg)
4. Height (cm)
5. Percent body fat
6. Skinfolds at the sites of: (mm)
   a) Abdominal
   b) Tricep
   c) Bicep
   d) Subscapular (back)
   e) Supra-iliac
   f) Chest
   g) Thigh

To compare the predictability of percent body fat in 18 - 25 year old Turkish males by using various other regression equations that are in the literature, paired-t-tests were used to see if there were any significant differences at the .05 level between the means of the predicted percent body fat values obtained from other equations including the newly developed equation and underwater weighing.

CHAPTER IV

RESULTS AND DISCUSSION

This study was designed to develop regression equations to predict percent body fat from anthropometric measurements of skinfolds from seven sites, weight and height by using underwater weighing as criterion. Secondly, different prediction equations, developed in other countries were evaluated to determine their validity on the present group of subjects. Finally, the anthropometric measurements of the Turkish population were compared with the measurements of other countries where data was available.

The results are presented as follows: physical characteristics of the subjects, results of multiple regression analyses, use of different existing prediction equations on the present group of subjects, and comparison of anthropometric measurements of Turks with the ones of other countries.

Physical Characteristics of the Subjects

A total of one hundred eighty-four 18 - 25 year old Turkish males were studied in three groups. Eighty-four university students representing seven geographical regional sub-groups comprised the first group representing the total Turkish population. These were subjects on which satisfactory underwater weight has been obtained. The second and third groups consisted of fifty subjects each, representing the urban and rural non-student population of Ankara respectively.

Descriptive data on all one hundred eighty-four subjects of this study are shown in Table III. Means ($\bar{X}$) and standard deviations (S.D.) are given for age, weekly exercise, weight, height, skinfold measurements of seven sites, and percent body fat variables.

Every one of these variables were analyzed statistically to see if there were any significant differences between the means of the seven geographical regional sub-groups (see Table IV) and between the means of the three groups (see Table V). The significance level of .05 was selected for all statistical analyses.

The results showed that there were no pairs of groups among the seven geographical region sub-groups significantly different at the .05 level for any one of the variables (see Table IV).

Comparing the means of the three groups (university students, urban non-students, and rural non-students), the results showed that there were no pairs of groups among the three groups significantly different at the .05 level for the tricep, bicep, thigh and chest, skinfolds and percent body fat variables. But, there were pairs of groups among the three groups significantly different at .05 level for the age, weekly exercise, weight, abdominal skinfold, subscapular (back) skinfold, and supra-iliac skinfold variables (see Table V). The results of multiple range tests (Student-Newman-Keul Procedure) identifying the pairs of groups significantly different at the .05 level are shown in Table VI.

Results of Multiple Regression Analyses

The underwater weighing method of obtaining percent body fat was

TABLE III

ANTHROPOMETRIC MEASUREMENTS OF YOUNG TURKISH MEN

Groups		1 (University Students)								(Urban Non- 2 St'dt)	(Rural Non- 3 St'dt)	2 + 3	Total
Regions		1	2	3	4	5	6	7	Total				
Number of Subjects		16	17	13	11	13	9	5	84	50	50	100	184
Age (Years)	X̄	22.3	22.0	21.9	23.1	21.3	22.0	21.2	22.0	20.5	20.2	20.4	21.1
	S.D.	1.58	1.80	1.63	1.51	2.10	0.87	0.45	1.66	2.39	2.53	2.46	2.28
Weekly Exercise (Hour)	X̄	11.2	11.2	9.9	11.2	11.0	11.9	5.6	10.8	7.8	3.7	5.8	8.1
	S.D.	± 9.839	± 7.020	± 7.112	± 8.256	± 8.737	± 8.115	± 1.342	± 7.875	±9.110	±5.989	±7.942	±8.271
Weight (kg)	X̄	66.950	68.347	73.585	67.391	70.231	61.867	70.160	68.471	63.710	61.290	62.620	65.429
	S.D.	±10.747	± 8.065	± 5.811	±11.148	± 8.834	± 5.549	± 8.947	± 9.026	±7.024	±7.156	±7.147	±8.595
Height (cm)	X̄	172.44	175.88	179.23	174.09	174.39	171.33	174.40	174.70	--	--	--	--
	S.D.	± 5.48	± 8.69	± 4.66	± 6.20	± 6.90	± 6.33	± 5.55	± 6.76	--	--	--	--
Abdominal (mm)	X̄	12.4	13.8	16.0	14.0	15.0	10.4	15.9	13.9	11.8	11.9	11.0	12.8
	S.D.	± 5.56	± 4.13	± 3.48	± 4.38	± 5.50	± 2.99	± 4.01	± 4.94	±5.11	±5.46	±5.46	±5.31
Tricep (mm)	X̄	7.5	8.0	10.1	7.7	9.0	6.7	10.4	8.4	8.2	8.3	8.3	8.3
	S.D.	± 2.73	± 2.03	± 3.47	± 2.73	± 3.49	± 2.58	± 2.16	± 2.95	±3.33	±3.26	±3.26	±3.31
Bicep (mm)	X̄	3.2	3.6	4.3	3.6	4.2	3.1	3.5	3.7	4.0	4.1	4.0	3.9
	S.D.	± 1.13	± 1.06	± 1.41	± 1.08	± 1.18	± 0.96	± 0.50	± 1.16	±1.46	±1.84	±1.66	±1.46
Subscapular (mm)	X̄	9.8	9.9	12.0	11.3	11.7	8.5	10.7	10.6	9.9	8.8	9.4	9.9
	S.D.	± 3.13	± 3.15	± 3.80	± 3.31	± 3.34	± 1.54	± 0.98	± 3.20	±3.18	±2.85	±3.06	±3.17
Supra-Iliac (mm)	X̄	10.6	11.0	13.6	10.7	13.1	9.3	11.3	11.5	10.0	9.4	9.7	10.5
	S.D.	± 4.15	± 3.80	± 6.03	± 3.78	± 5.54	± 3.95	± 3.49	± 4.61	±4.95	±4.81	±4.87	±4.82
Thigh (mm)	X̄	10.0	11.5	13.5	9.9	11.7	10.5	13.3	11.3	11.0	10.8	10.9	11.1
	S.D.	± 3.25	± 2.51	± 4.48	± 3.70	± 4.33	± 3.91	± 2.23	± 3.71	±3.99	±4.31	±4.13	±3.94
Chest (mm)	X̄	5.0	5.5	5.8	5.4	5.9	4.4	5.5	5.4	6.0	5.0	5.5	5.5
	S.D.	± 1.68	± 1.63	± 2.14	± 1.68	± 2.52	± 1.69	± 1.00	± 1.86	±3.38	±1.96	±2.79	±2.40
Body Fat*	X̄	12.7	13.9	15.7	13.5	14.6	11.6	15.6	13.9	12.6	12.6	12.6	13.2
	S.D.	± 4.01	± 2.80	± 3.93	± 3.32	± 3.90	± 2.36	± 1.79	± 3.54	±3.66	±4.28	±3.96	±3.82

*Calculated From Regression Equation (See Table VIII)

TABLE IV

ANALYSIS OF VARIANCE SUMMARIES OF SEVEN GEOGRAPHICAL REGION SUB-GROUPS

Group 1

Variables	Mean Square		F
	Between Groups	Within Groups	
Age (Year)	: 4.06	2.64	1.53
Weekly Exercise (Hour)	: 28.02	64.66	0.43
Weight (kg)	:139.52	76.94	1.81
Height (cm)	: 80.06	43.08	1.86
Body Fat (%)	: 22.85	11.72	1.95
Skinfolds (mm)			
Abdominal	: 40.08	23.20	1.73
Tricep	: 17.64	7.99	2.21
Bicep	: 2.36	1.27	1.86
Subscapular (Back)	: 17.46	9.69	1.80
Supra-Iliac	: 26.20	20.90	1.25
Thigh	: 23.14	13.06	1.78
Chest	: 2.66	3.51	0.76

N = 84

D.F. = Between Groups 6
Within Groups 77
Total 83

No two pairs of groups significantly different at the .05 level

TABLE V

ANALYSIS OF VARIANCE SUMMARIES OF STUDENT URBAN-RURAL GROUPS

Variables	Mean Square		F
	Between Groups	Within Groups	
Age (Year)	63.56	4.55	13.98*
Weekly Exercise (Hour)	774.38	60.62	12.78*
Weight (kg)	813.79	65.27	12.47*
Height (cm)	--	--	--
Body Fat (%)	38.29	14.34	2.67
Skinfolds (mm)			
Abdominal	92.52	27.50	3.37*
Tricep	0.68	9.80	0.07
Bicep	3.56	2.11	1.68
Subscapular (Back)	48.75	9.63	5.06*
Supra-Iliac	74.43	22.65	3.29*
Thigh	5.04	15.66	0.32
Chest	11.76	5.77	2.06

N = 184

D.F. = Between Groups 2
Within Groups 181
Total 183

*Significant at the .05 level

(See Table VI for the pairs of groups significantly different at the .05 level.)

TABLE VI

MULTIPLE RANGE TEST "STUDENT-NEWMAN-KEUL-PROCEDURE"

Variable	Groups	Means	3 (Rural)	2 (Urban)	1 (Student)
Age (Year)	3 (Rural)-	20.22			
	2 (Urban)-	20.52	*		
	1 (Student)-	22.02	*	*	
Weekly Exercise (Hour)	3 (Rural)-	3.74			
	2 (Urban)-	7.84			
	1 (Student)-	10.76	*	*	
Weight (kg)	3 (Rural)-	61.29			
	2 (Urban)-	63.71			
	1 (Student)-	68.47	*	*	
Abdominal Skinfold (mm)	2 (Urban) -	11.80			
	3 (Rural) -	11.89			
	1 (Student)-	13.86		*	
Subscapular (Back) Skinfold (mm)	3 (Rural)-	8.79			
	2 (Urban)-	9.92			
	1 (Student)-	10.55	*		
Supra-Iliac Skinfold (mm)	3 (Rural)-	9.39			
	2 (Urban)-	10.01			
	1 (Student)-	11.45	*		

*Denotes pairs of groups significantly different at the .05 level performed only on the subjects of the group one (N = 84). These results were used as criterion (dependent variable) in the multiple regression analyses.

The results of multiple regression analysis using seven skinfold sites as independent variables, revealed that the abdominal skinfold had the highest correlation (r = .638) with the percent body fat. Correlation coefficients of each skinfold are shown in Table VII (Simple R). Independently the abdominal skinfold accounted for only 40.76% of variation in the percent body fat. The second step of the multiple regression analysis showed that the thigh skinfold together with the abdominal skinfold had a higher correlation (r = .673) than any other when combined with the abdominal skinfold. Combined abdominal and thigh skinfolds accounted for 45.3% of variation in the percent body fat. As the steps progressed further in the multiple regression analysis the percentage of variation accounted for in the percent body fat increased to 47.69% when all seven skinfolds were included. But, as the multiple regression analysis showed, this increase was not significant after the second step which included only the abdominal and the thigh skinfolds.

When the residuals of the predicted to actual percent body fat results were plotted on a graph, the predicted percent body fat of one subject fell outside the ±2 standard deviation range. After deletion of that data the results of the second multiple regression analysis showed that abdominal and thigh skinfolds combined accounted for an increased percent of variation (from 45.31% to 50.61%) in the percent body fat with a .71 multiple correlation coefficient (See Table VIII).

TABLE VII

SUMMARY-RELATIONSHIPS OF SKINFOLD THICKNESSES (X_1-X_7)
TO THE REGRESSION EQUATION TO PREDICT
PERCENT BODY FAT (PCBF)

Variables (Skinfolds)	Simple R	Multiple R	R Square
X_1: Abdominal	.63844	.68844	.40760
X_2: Thigh	.51706	.67313	.45310
X_3: Chest	.59522	.68204	.46518
X_4: Supra-Iliac	.53041	.68997	.47606
X_5: Tricep	.57370	.69040	.47665
X_6: Bicep	.52176	.69052	.47681
X_7: Subscapular (Back)	.53696	.69057	.47688

Regression

$$PCBF = 2.63415 + .5128552X_1 + .281711X_2 + .5769225X_3 - .2456491X_4 + .06895029X_5 + .08122993X_6 + .02745566X_7$$

N = 84

Standard Error = 3.82887

TABLE VIII

SUMMARY-RELATIONSHIPS OF SKINFOLD THICKNESSES (X_1 AND X_2) TO THE REGRESSION EQUATION TO PREDICT PERCENT BODY FAT (PCBF)

Variables (Skinfolds)	Simple R	Multiple R	R Square	Regression
X_1: Abdominal	.68964	.68964	.46560	$PCBF = 2.662566 + .5819738X_1 + .2770687X_2$
X_2: Thigh	.51863	.71138	.50606	N = 83 Standard Error: 3.54809

The standard error of prediction which was ±3.83 in the first regression equation using all seven skinfolds was lower (±3.55) in the second regression equation using only abdominal and thigh skinfolds.

The distribution of the residuals of the predicted to the actual percent body fat is shown in Figure 2. This distribution as shown on the graph was in a shot-gun fashion and did not have any specific shape to require any special adjustment for sampling errors.

A table (Figure 3) was drawn to determine the predicted percent body fat from abdominal and thigh skinfold measurements without any mathematical calculations. In this table, thigh skinfold value is located in the horizontal axis, at the top of the table and abdominal skinfold value is located in the vertical axis, at the left side of the table. The approximate percent body fat is then found at the point where these two axes intersect. For example: If a subject had an abdominal skinfold measurement of 10 mm and a thigh skinfold measurement of 17 mm, then his percent body fat value would be 13.

A nomogram (Figure 4) was prepared also to determine predicted percent body fat value from abdominal and thigh skinfold measurements without any mathematical calculations. To obtain percent body fat value, thigh and abdominal skinfold values are marked and a straight line drawn between these two marks. The value shown at the point this line intersects the vertical scale representing the percent body fat values is the value of predicted percent body fat. For example: If a subject had an abdominal skinfold measurement of 20 mm and a thigh skinfold measurement of 21 mm, then his percent body fat value would be 20.

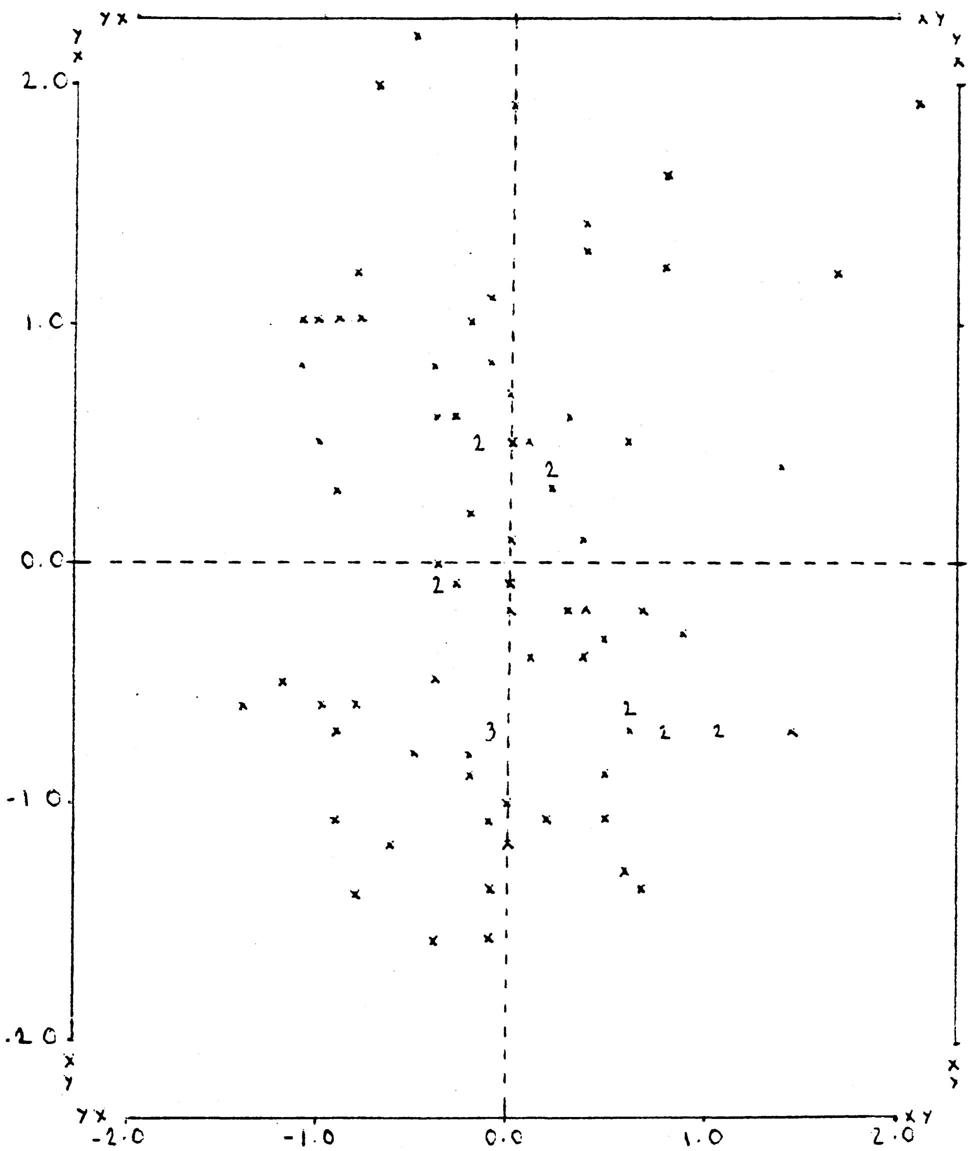

Figure 2. Distribution of Predicted Percent Body Fat Residuals

Plot: X

Down - Residual-Difference between percent body fats from underwater weight and skinfolds

Across - Predicted Percent Body Fat

Thigh Skinfold (mm)

Abdominal Skinfold (mm) \ Thigh Skinfold (mm)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
5	6	7	7	7	8	8	8	8	9	9	9	10	10	10	10	11	11	11	11	12	12	12	13	13	13	13	14	14	14	14	15	15	15	16
6	7	7	8	8	8	8	9	9	9	10	10	10	10	11	11	11	11	12	12	12	13	13	13	13	14	14	14	15	15	15	15	16	16	16
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20	15	15	16	16	16	17	17	17	17	18	18	18	19	19	19	19	20	20	20	20	21	21	21	22	22	22	22	23	23	23	23	24	24	24
21	16	16	16	17	17	17	17	18	18	18	19	19	19	19	20	20	20	20	21	21	21	22	22	22	22	23	23	23	24	24	24	24	25	25
22	16	17	17	17	17	18	18	18	19	19	19	19	20	20	20	21	21	21	21	22	22	22	22	23	23	23	24	24	24	24	25	25	25	25
23	17	17	17	18	18	18	19	19	19	19	20	20	20	21	21	21	21	22	22	22	22	23	23	23	24	24	24	24	25	25	25	26	26	26
24	18	18	18	18	19	19	19	19	20	20	20	21	21	21	21	22	22	22	23	23	23	23	24	24	24	24	25	25	25	26	26	26	26	27
25	18	18	19	19	19	19	20	20	20	21	21	21	21	22	22	22	23	23	23	23	24	24	24	24	25	25	25	26	26	26	26	27	27	27
26	19	19	19	20	20	20	20	21	21	21	21	22	22	22	23	23	23	23	24	24	24	24	25	25	25	26	26	26	26	27	27	27	28	28
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32	22	22	23	23	23	24	24	24	24	25	25	25	25	26	26	26	27	27	27	27	28	28	28	29	29	29	29	30	30	30	30	31	31	31
33	23	23	23	24	24	24	24	25	25	25	26	26	26	26	27	27	27	27	28	28	28	29	29	29	29	30	30	30	31	31	31	31	32	32
34	23	24	24	24	24	25	25	25	26	26	26	26	27	27	27	27	28	28	28	29	29	29	29	30	30	30	31	31	31	31	32	32	32	32
35	24	24	24	25	25	25	26	26	26	26	27	27	27	28	28	28	28	29	29	29	29	30	30	30	31	31	31	31	32	32	32	33	33	33
36	24	25	25	25	26	26	26	26	27	27	27	28	28	28	28	29	29	29	29	30	30	30	31	31	31	31	32	32	32	33	33	33	33	34
37	25	25	26	26	26	26	27	27	27	28	28	28	28	29	29	29	30	30	30	30	31	31	31	31	32	32	32	33	33	33	33	34	34	34
38	26	26	26	26	27	27	27	28	28	28	28	29	29	29	30	30	30	30	31	31	31	31	32	32	32	33	33	33	33	34	34	34	35	35

Figure 3. Conversion Table

Conversion of Skinfold Thicknesses to Percent Body Fat in Turkish Men 18 - 25 Years Old

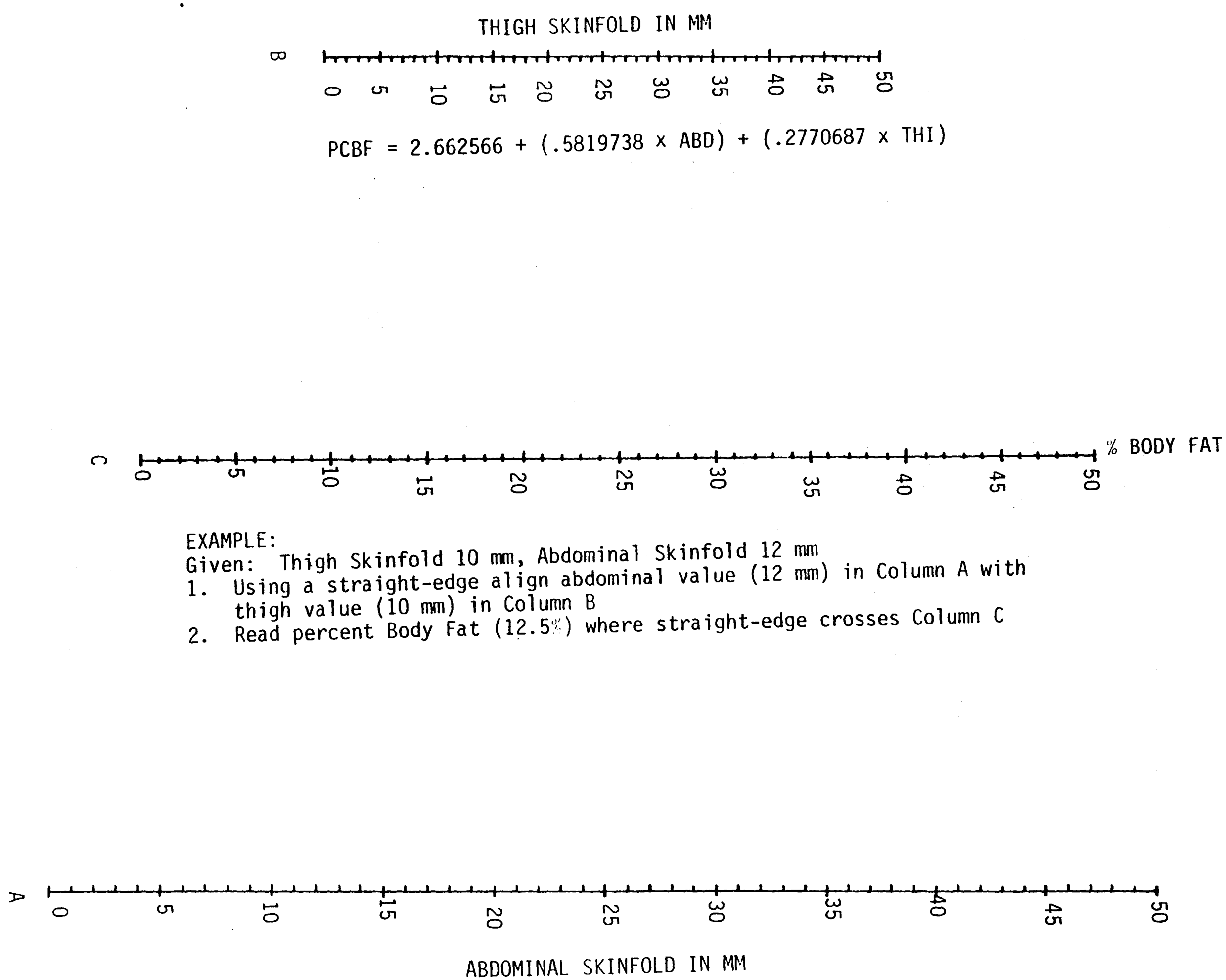

Figure 4. Nomogram
Conversion of Skinfold Thickness to Percent Body Fat in Turkish Men 18 - 25 years Old

Comparison of the Predictability of Various Equations on the Present Group of Subjects

For this comparison a Japanese, a British, an American, and a generalized equation were used. The characteristics of these four equations are as follows. The Japanese equation was based on arm (tricep) and subscapular skinfolds and developed in a study using ninety-six 18 - 27 year old Japanese males (Nagamine et al., 1964). The British equation was based on log of sum of bicep, tricep, and supra-iliac skinfolds and developed in a study using ninety-two 20 - 29 year old British males (Durnin et al., 1974). The American equation was based on abdominal, chest, and arm (tricep) skinfolds and was developed in a study using one hundred sixteen 18 - 26 year old American males (Brozek et al., 1951). The generalized equation was based on chest, abdominal, and thigh skinfolds and also included the age in the equation to be used for males in any age group (Pollock et al., 1979).

Through paired-t-tests, the means of the predicted percent body fats of the eighty-four university student subjects of this study obtained by the four regression equations mentioned above and the new developed regression equation (Eq. Gazo) were compared with the true percent body fats of the same subjects obtained by underwater weighing. The results revealed (see Table IX) that there were significant differences at the .05 level between the means of the predicted percent body fats obtained by Japanese, American and generalized equations and mean of the true percent body fats obtained by underwater weighing. There were no significant differences between the means of the predicted percent body fats obtained by British and the newly developed equation

TABLE IX

COMPARISON OF THE PREDICTABILITY OF JAPANESE (Eq. J.), BRITISH (Eq. Br.), AMERICAN (Eq. Am.), GENERALIZED (Eq. W.), AND NEW (Eq. Gazo) REGRESSION EQUATION ON THE 18-25 YEAR OLD TURKISH MEN

Equations	Mean	S.D.	S.E.	Mean Difference	Corr.	t	2-Tail Prob.
Eq. J.	11.57	2.42	.26	-2.49	.61	- 5.62	.000
Eq. Br.	14.03	3.72	.41	-0.03	.59	- 0.06	.951
Eq. Am.	8.33	2.79	.30	-5.73	.67	-13.84	.000
Eq. W.	6.27	2.27	.25	-7.79	.65	-18.11	.000
Eq. Gazo	13.87	3.54	.30	-0.19	.67	- 0.46	.648

With

Underwater Weighing Method	14.06	5.07	.55

(Degree of freedom = 183, Paired-t-test)

Eq. J. (Nagamine, et al., 1964) N = 96 18-27 year
PCBF = 4.201 ÷ (1.0913-.00116 [Arm + Subscapular])-3.813x100

Eq. Br. (Durnin, et al., 1974) N = 92 20-29 year
PCBF = 4.95 ÷ (1.162-.0630xlog [Bicep + Tricep + Subscapular + Supra-iliac]) - 4.50x100

Eq. Am. (Brozek, et al., 1951) N = 116 18-26 year
PCBF = 5.548 ÷ (1.1017-.000282 [Abdominal]-.000736 [Chest]-.000883 [Arm]) - 5.044x100

Eq. W. (Pollock et al., 1979)
PCBF = 4.95 ÷ (1.10938-.0008267 [Chest + Abdominal + Thigh] +.0000016 [Chest + Abdominal + Thigh]^2+.0002574 [Age] -4.50x100

Eq. Gazo (Present Study)
PCBF = 2.662566+.5819738 [Abdominal] +.2770687 [Thigh]

and the mean of the true percent body fats obtained by underwater weighing. The correlation coefficient of the new equation (Eq. Gazo) to the true value was higher (r = .76) than the British equation (r - .59). The British equation had a smaller mean difference to the true value (- .0278) and had higher probability showing that this relationship occurs more systematically. The new equation had a mean difference of - .1882 and a lower probability showing that this relationship occurs less systematically yet not significant at the .05 level. The new equation had standard deviation of 3.538 percent fat with a standard error of .386, whereas the British equation had standard deviation of 3.722 percent fat with a standard error of .406.

Comparison of the Anthropometric Measurements of Various Countries Around the World

The average anthropometric measurements of young adults (19 - 28 years old) of various countries around the world are shown in Table X. The table includes the heights, weights, percent body fats, and skin-fold measurements of tricep, bicep, subscapular (back), supra-iliac, thigh, chest, and abdominal.

Table X shows that the ranges of these measurements are very wide (see New Guina Papuans and USA in Table X). In general, the new Guina population has the lowest norms and USA population has the highest norms. These variations that are seen between countries also occur within a country's population. For example: the New Guina Papuans at Mappia has the lowest norms when compared to the ones at Sorong and Biak except their thigh skinfolds are thicker than others, and the New Guina Papuans at Biak have the highest norms except their

TABLE X

ANTHROPOMETRIC MEASUREMENTS OF YOUNG MEN FROM VARIOUS COUNTRIES

Country	People or Place	Aged N	Authors	Height (cm)	Weight (kg)	Tricep (mm)	Bicep (mm)	Subscapular (mm)	Supra-iliac (mm)	Thigh (mm)	Chest (mm)	Abdominal (mm)	Percent Body Fat
New Guina Papuans	Biak	20-29 N=9	Jansen, 1963	157.3	45.3	4.4	3.2	6.8	4.8	6.0	--	5.8	--
New Guina Papuans	Sorang	20-29 N=6	Jansen, 1963	161.0	55.0	5.2	2.8	7.8	4.8	5.8	--	4.8	--
New Guina Papuans	Mappia	20-29 N=9	Jansen, 1963	147.0	37.7	3.3	2.0	6.3	4.8	6.3	--	4.8	--
Australia Aborogine	Darwin	$\bar{X}$ = 21 N=9	Elsner, 1963	169.0	61.0	8.0	--	3.0	--	--	6.0	11.0	--
Australia Aborogine	Darwin	25-29 N=22	Abbie, 1967	168.6	56.2	4.7	--	8.7	--	--	--	--	--
Australia Aborogine	Pitjandjara	$\bar{X}$ = 19 N=8	Elsner, 1963	173.0	57.0	6.0	--	10.0	--	--	4.0	7.0	--
Canada	Eskimos	$\bar{X}$ = 25 N=16	Elsner, 1963	163.0	61.0	6.0	--	7.0	--	--	4.0	5.0	--
Africa (Athlete)	Ghana	$\bar{X}$ = 24 N=120	Watson, et al., 1977	174.0	66.6	4.7	3.4	8.5	7.5	--	--	--	10.4
Africa (Athlete)	Nigeria	$\bar{X}$ = 24 N=68	Watson, et al., 1977	175.0	68.0	4.9	3.6	9.0	7.5	--	--	--	11.2
Africa (Athlete)	Liberia	$\bar{X}$ = 22 N=40	Watson, et al., 1977	173.0	65.3	5.2	3.4	8.3	8.0	--	--	--	10.9
Africa (Athlete)	W. Africa	$\bar{X}$ = 23 N=395	Watson, et al., 1977	174.0	67.5	4.9	3.4	8.6	7.6	--	--	--	10.9
Africa (Athlete)	Egypt	$\bar{X}$ = 22 N=41	Watson, et al., 1977	181.0	77.0	6.1	3.6	8.9	10.4	--	--	--	12.8
Africa (Athlete)	Algeria	$\bar{X}$ = 23	Watson, et al., 1977	176.0	71.1	4.4	3.1	7.8	8.3	--	--	--	10.7

TABLE X (Continued)

Country	People or Place	Aged N	Authors	Height (cm)	Weight (kg)	Tricep (mm)	Bicep (mm)	Subscapular (mm)	Supra-iliac (mm)	Thigh (mm)	Chest (mm)	Abdominal (mm)	Percent Body Fat
Japan	National	18-27	Nagamine et al., 1964	167.2	58.9	8.0	--	10.9	--	--	8.0	8.7	--
Poland	Warsaw	18	Charzewska, 1973	174.4	66.1	7.9	--	9.5	--	--	--	--	--
Poland	Rural	18	Volanski, 1976	165.2	60.3	6.6	--	5.1	--	--	--	--	--
USA	National	18-24 N=411	Stoudt, et al., 1965	174.5	72.6	9.0	--	13.0	--	--	--	--	--
USA	National (White)	17-28 N=2017	Newman, 1955	--	70.0	11.4	--	--	13.6	--	10.0	14.6	7.4
USA	National (Black)	17-28 N=361	Newman, 1955	--	68.6	8.2	--	--	12.2	--	6.5	11.7	4.6
USA	Northern (White)	17-28 N=1283	Newman, 1955	--	71.1	12.0	--	--	14.2	--	10.6	15.3	7.9
USA	Southern (White)	17-28 N=713	Newman, 1955	--	68.3	10.4	--	--	12.4	--	9.0	13.4	6.4
Turkey	National	18-25 N=184	Present Study	--	65.4	8.3	3.9	9.9	10.5	11.1	5.5	12.8	13.2
Turkey	Student	18-25 N=84	Present Study	174.7	68.5	8.4	3.7	10.6	11.5	11.3	5.4	13.9	13.9
Turkey	Non-Student	18-25 N=100	Present Study	--	62.6	8.3	4.0	9.4	9.7	10.9	5.5	11.9	13.2
Turkey	Military	24.1 N=915	Hertzberg, et al., 1977	169.29	64.61	7.7	--	10.1	--	--	7.2	--	9.4
Greece	Military	22.9 N=1084	Hertzberg, et al., 1977	170.51	67.03	9.2	--	11.4	--	--	8.5	--	10.4
Italy	Military	26.5 N=1358	Hertzberg, et al., 1977	170.60	70.26	11.1	--	13.9	--	--	12.3	--	12.3

subscapular (back) skinfold norm is lesser than the ones at Sorong. Such differences are also in USA where black Americans' norms are lower than white Americans' norms or just among white Americans, the Northerners' norms are higher than Southerners'. The differences are seen between the urban and rural populations as it shows by Polish norms where the norms of Polish in Warsaw are higher than their rural counterparts.

Discussion

This study was designed to determine the predictability of percent body fat from skinfold measurements on 18 - 25 year old Turkish male population to develop a regression equation to predict percent body fat from skinfold measurements, and to compare the predictability of the other equations in the literature on the present group of subjects.

Accurate estimate of percent body fat can be accomplished through laboratory methods such as underwater weighing, radiography, or gamma ray spectrometry. However, proper execution of these procedures is limited by time, cost, equipment, and availability of trained personnel. Therefore, a practical field method using only skinfold calipers became popular in estimating the percent body fat. Several investigators have addressed the problem of estimating the percent body fat from skinfold measurements and they agreed that the regression equations used for calculation of percent body fat are very population specific due to variables such as bone structure, height, weight, age, sex, race, and the location of the individual's fat stores (Katch and McArdle, 1973; Wilmore and Behnke, 1968; Pollock et al., 1973; Durnin and Womersley, 1974; Fleck and Hagerman, 1980).

A total of one hundred eighty-four males (mean age = 21± 2.3 years) volunteered for this study. Eighty-four of the subjects were university students (mean age = 22± 1.6 years) representing the total population (seven geographical region sub-groups), fifty of the subjects were urban non-students from the city of Ankara (mean age = 20.5± 2.5 years), and fifty of the subjects were rural non-students from the villages surrounding the city of Ankara (mean age = 20.2± 2.5 years). The first group of subjects (N = 84, university students) percent body fats were estimated through the underwater weighing method. Weight, height, and skinfold measurements of abdominal, tricep, bicep, subscapular (back), supra-iliac, chest, and thigh measurements were taken on all one hundred eighty-four subjects. Stepwise multiple regression analysis was used to determine the best combination of indicators (skinfolds) to predict percent body fat. The underwater weighing results were used as criterion. Significance of the differences were checked between seven geographical region subgroups and between university students, urban non-students, and rural non-student groups. Through paired-t-tests validity checks were done for the new regression equation and four other regression equations used around the world. Lastly, the anthropometric measurements of Turkish subjects were compared with the norms of the other countries that were available in the literature.

When the means of the seven geographical region sub-groups were compared for each of the variables (age, weekly exercise, weight, height, percent body fat, skinfolds of abdominal, tricep, bicep, subscapular, supra-iliac, chest and thigh), there were no pairs of subgroups significantly different at the .05 level. Analysis of variance showed also that there were no significant differences at the .05 level between the university student, urban non-student and rural non-student groups except the following:

Age - significant difference at the .05 level between all three groups

Weekly exercise - significant difference at the .05 level between university student group and non-student groups

Weight - significant difference at the .05 level between university student group and non-student groups

Abdominal skinfold - significant difference at the .05 level between university student group and rural non-student group

Subscapular skinfold - significant difference at the .05 level between university student group and rural non-student group

Supra-iliac skinfold - significant difference at the .05 level between university student group and rural non-student group.

The results of multiple regression analysis for prediction of percent body fat from all seven skinfold measurements indicated a multiple R of .69 with standard error of 3.8 percent fat. Second multiple regression analysis after eliminating one subject's data whose predicted percent body fat residual fell outside the standard range, indicated a multiple R of .71 for the abdominal and thigh skinfolds alone (S.E. = 3.5% fat).

In comparing the mean percent body fats obtained from four other selected equations and the new equation with the one obtained through underwater weighing method (true value), Japanese, American and the generalized equations showed to have significant differences at the .001 level. The British equation did not have a significant mean difference at the .05 level, but had larger standard deviation and standard error (S.D. = 3.72, S.E. = .41) than the newly developed equation (S.D. = 3.54, S.E. = .39).

When the anthropometric measurements of young Turks 18 - 25 years of age were compared with the norms of other countries of similar age groups, Turks showed to have higher values than Japanese, Polish, Africans, Papuans of New Guina, Aborogines of Australia, and black Americans. The Turks demonstrated lower values than white Americans, Greeks and Italians. The percent body fat norms of all populations reported in Table X was lower than what was considered to be as optimal range of 16-19% in the United States for young healthy males (Pollock et al., 1978). Newman's (1955) national norms for the United States white and black populations showed very low percent body fat values, when the skinfold values that he reported were considered. This might be due to the Brozek and Keys (1951) formula that was used in the calculation of the body fats of both white and black Americans. The percent body fat values for the Turkish military personnel reported by Hertzberg et al., (1977) were also considerably lower than the ones of the present group of subjects, even though the weight and skinfold measurements of both reports were compatible. This definitely was due to the estimation error of the equation used by Hertzberg et al., (1977), on estimation of the percent body fat values of Turkish military personnel. Therefore, when the percent body fat values of various countries' people were compared, the differences and/or similarities would not have been drawing the true picture due to the different equations used in estimations. Such comparison would have been possible when all percent body fat values were obtained through the same method such as underwater weighing.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Even though, the study of body composition goes far back into the past, impetus for the study of fat (as other than a superficial) variable) has come from research relating the amount of fat to the probability of death (Wilmer, 1940).

Obesity is a pathological condition characterized by an accumulation of fat much in excess of that necessary for optimal body function. It is mainly associated with excessive calorie intake, and is widespread in children and adults in most privileged parts of the world. It is mainly from easy accesibility to foods, especially high-calorie fats, together with insufficient exercise (Jelliffe, 1976).

While there are many methods, physical anthropometry using skinfold calipers is the most practical method to measure percent body fat. But, the regression equations used for calculations of percent body fats are population specific (Katch and McArdle, 1973). Therefore, the purpose of this study was to develop a regression equation to predict percent body fats of 18 - 25 year old Turkish males through skinfold measurements. It was also the purpose of this study to compare the anthropometric measurements of Turks with the ones from other countries where the data was available in the literature. A secondary purpose of this study was to determine the validity of different prediction equations developed in other countries on the Turkish males.

A total number of 184 subjects were tested for this study. They were all 18 - 25 years old and divided into three groups. The first group consisted of 84 university students in seven geographical region sub-groups representing the total Turkish population. The second and third groups consisted of 50 subjects each representing the urban and rural non-student population of Ankara respectively.

One way analysis of variance tests were used to determine the differences among the seven geographical region sub-groups and among the groups on everyone of the variables tested (age, weekly exercise, weight, height, percent body fat, and skinfolds of abdominal, tricep, bicep, subscapular, supra-iliac, thigh and chest).

Multiple t-tests were used to determine the validity of the different equations on the present group of subjects.

Stepwise multiple regression analysis was used to obtain the regression equation.

In all statistical analyses .05 was selected as the confidence level.

Conclusions

Within the stated limitations, the following conclusions were made based on the results of this study:

1. The mean values of all variables tested were not significantly different among seven geographical regional sub-groups. Therefore, the first null hypothesis was accepted.

2. There was no significant difference between the means of

tricep, bicep, subscapular, supra-iliac, thigh and chest skinfolds and percent body fat measurements of student and non-student urban males. Therefore, the second null hypothesis was accepted in regards to these variables. There was a significant difference between the means of age, weekly exercise, weight and abdominal skinfolds measurements of student and non-student urban males. Therefore, the second null hypothesis was rejected in regards to these variables.

3. There was no significant difference between the means of abdominal, tricep, bicep, thigh and chest skinfolds and percent body fat measurements of student and non-student rural males. Therefore, the third null hypothesis was accepted in regards to these variables. There was a significant difference between the means of age, weekly exercise, weight and subscapular and supra-iliac skinfolds measurements of students and non-student rural males. Therefore, the third null hypothesis was rejected in regards to these variables.

4. There was no significant difference between the means of weekly exercise, weight, percent body fat and abdominal, tricep, bicep, subscapular, supra-iliac, thigh and chest skinfolds measurements of non-student urban and rural males. Therefore the fourth null hypothesis was accepted in regards to these variables. There was a significant difference between the means of age of non-student urban and rural males. Therefore, the fourth null hypothesis was rejected in regards to these variables.

5. There was no significant difference between the mean of the percent body fat values obtained through underwater weighing method and the mean of the predicted percent body fat values obtained through the British (Durnin et al., 1974) equation. Therefore, the fifth

null hypothesis was accepted in regards to these variables. There were significant differences between the means of the percent body fat values obtained through underwater weighing and the means of the predicted percent body fat values obtained through the Japanese (Nagamine et al., 1964), the American (Brozek et al., 1951) and the generalized (Pollock et al., 1979) regression equations. Therefore, the fifth null hypothesis was rejected in regards to these variables.

6. Even though the British (Durnin et al., 1974) regression equation estimated the percent body fat values on the present group of subjects not significantly different, the standard deviation and the standard error of estimation were larger than the newly developed equation (Eq. Br. = .41 ± 3.72%; Eq. Gazo = .39 ± 3.54%).

7. The final regression equation developed was:

   $PCBF = 2.662566 + .5819738X_1 + .2770687X_2$

   where: X_1 = abdominal skinfold measurement

   X_2 = thigh skinfold measurement

   with Multiple R = .71 and S.E. = 3.548%.

Recommendations

Realizing the limitation and the delimitations of this study, the following recommendations are made with regard to further studies to obtain more accurate regression equations to predict percent body fat:

1. Necessary tests should be done to ensure the reliability and validity of the measurements. For example: A small group selected randomly from the subjects used in the study could be tested again at different times and the results of body tests could be compared. More than one person could

give the same test to every student and the average values of both investigator's measurements could be used for statistical analyses.

2. Sampling should be done more scientifically to eliminate sampling errors. For example: The records of the University of Middle-East Technical University could have been used for selecting the subjects of the first group of this study.
3. Another study with forty or fifty 18 - 25 year old Turkish male subjects should be done to cross-validate the equation developed through this study.

The norms developed through this study for 18 - 25 year old Turkish male populations are by no means the most accurate. But, in the absence of others, these norms should be accepted to represent this specific population group.

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APPENDIXES

APPENDIX A

Personal Data Sheet

KISISEL DATA
(Personal Data)

ADA (First Name):

SOYADI (Last Name):

YASI (Age):

YASADIGI COGRAFI BOLGE (Geographic Area of Residency):

HAFTALIK BEDENI FAALIYETI - ZAMAN VE TUR (Weekly Physical Activity - Time and Type):

OLCULER (Measurements):

A) 1. AGIRLIK (Weight) _______

2. YUKSEKLIK (Height) _______

B) SKINFOLD BOLGESI (Area)

1. ABDOMINAL _______

2. TRICEP _______

3. BICEP _______

4. SUBSCAPULAR _______

5. SUPRAILIAC _______

6. THIGH _______

7. CHEST _______

C) SUALTI AGIRLIK OLCUSU (Underwater Weight Measurement)

1. BOS OTURAGIN AGIRLIGI (Weight of the Seat) _______

2. TOPLAM AGIRLIK (Total Weight

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

SU ALTI AGIRLIGI (Underwater Weight) _______

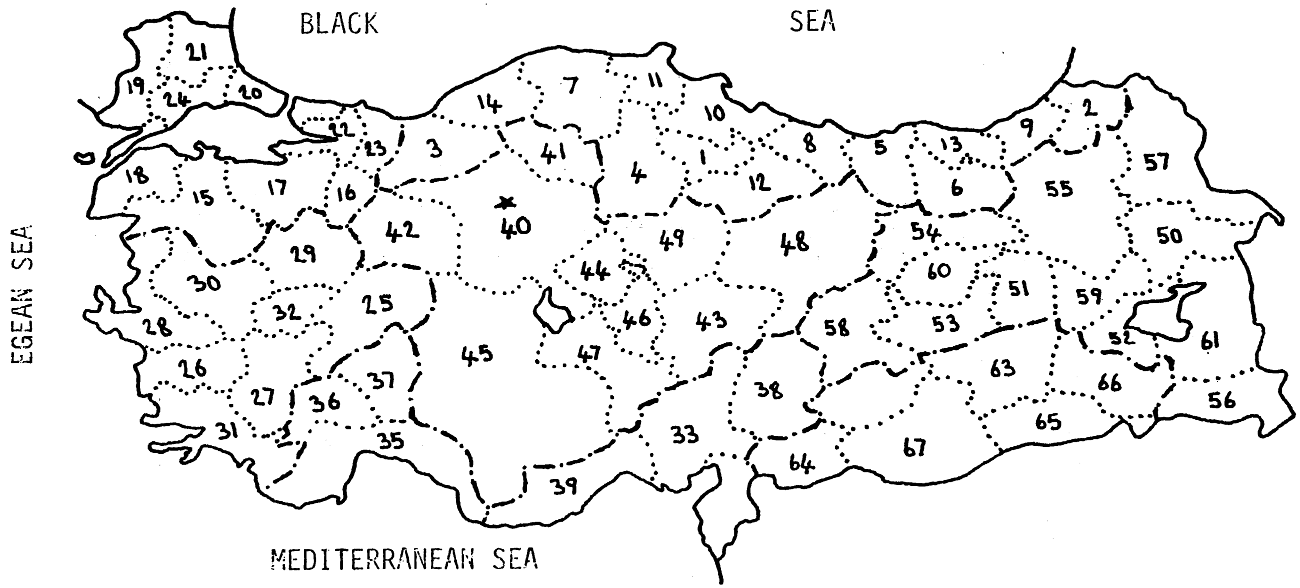
KG. DEGERI (In KG): (1 kg. = 2.2 lbs.) _______

APPENDIX B

Turkey's Provincial Map and

Population Distribution

TURKEY'S PROVINCIAL MAP



. . . Provincial Boundaries

- . - . Geographical Region Boundaries

TURKEY'S PROVINCIAL POPULATION DISTRIBUTION

Province names are the same as the administrative centers

I Black Sea Region

Province	Population
1. Amasya	341,287
2. Artvin	228,997
3. Bolu	471,751
4. Corum	571,831
5. Giresun	480,083
6. Gumushane	275,191
7. Kastamonu	450,946
8. Ordu	713,535
9. Rize	361,258
10. Samsun	1,008,113
11. Sinop	276,242
12. Tokat	624,508
13. Trabzon	731,045
14. Zonguldak	954,512
TOTAL	7,489,299

II Marmara Region

Province	Population
15. Balikesir	853,177
16. Bilecik	147,001
17. Bursa	1,148,492
18. Canakkale	391,568
19. Edirne	363,286
20. Istanbul	4,741,890
21. Kirklareli	283,408
22. Kocaeli	596,899
23. Sakarya	548,747
24. Tekirdag	360,742
TOTAL	9,435,210

III Egean Region

Province	Population
25. Afyon	597,516
26. Aydin	652,488
27. Denizli	603,338
28. Izmir	1,976,763
29. Kutahya	497,089
30. Manisa	941,941
31. Mugla	438,145
32. Usak	247,224
TOTAL	5,954,504

IV Mediterranean Region

Province	Population
33. Adana	1,485,743
34. Hatay	856,271
35. Antalya	748,706
36. Burdur	235,009
37. Isparta	350,116
38. Maras	738,032
39. Icel	843,931
TOTAL	5,257,808

V Central Anatolia Region

Province	Population
40. Ankara	2,854,689
41. Cankiri	258,436
42. Eskisehir	548,802
43. Kayseri	778,383
44. Kirsehir	240,497
45. Konya	1,562,139
46. Nevsehir	256,933
47. Nigde	512,071
48. Sivas	750,144
49. Yozgat	504,433
TOTAL	8,261,527

VI East Antolia Region

Province	Population
50. Agri	368,009
51. Bingol	228,702
52. Bitlis	257,908
53. Elazig	440,808
54. Erzincan	282,022
55. Erzurum	801,809
56. Hakkari	155,463
57. Kars	700,238
58. Malatya	606,996
59. Mus	302,406
60. Tunceli	157,974
61. Van	468,646
TOTAL	4,770,981

VII S.E. Anatolia Region

Province	Population
62. Adiyaman	367,595
63. Diyarbakir	778,150
64. Gaziantep	808,697
65. Mardin	564,967
66. Siirt	445,483
67. Urfa	602,736
TOTAL	3,567,628

APPENDIX C

Raw Data

ANTHRPOMETRIC MEASUREMENTS OF 18 - 25 YEAR OLD
TURKISH MALES

Sub-ject	Group	Sub-Group	Weight (kg)	U-Wei (kg)	SKINFOLDS (mm) ABD	Tri.	Bic.	Back	Iliac	Thi.	Che.
1	1	1	61.0	3.125	8.0	6.0	2.5	6.0	7.0	8.0	3.0
2	1	1	52.3	3.012	7.0	4.0	2.0	5.0	5.0	4.0	3.0
3	1	1	69.0	2.046	15.0	8.0	3.0	12.0	13.0	12.5	5.0
4	1	1	71.0	2.898	13.0	6.0	3.5	9.0	10.5	8.0	6.0
5	1	1	56.0	2.728	15.0	7.0	3.0	7.0	13.0	10.0	5.5
6	1	1	71.0	2.898	16.0	10.0	3.5	11.0	17.0	15.0	6.0
7	1	1	56.9	2.103	16.0	8.0	3.0	13.0	13.0	9.0	8.5
8	1	1	75.5	3.016	8.0	6.0	3.0	10.0	8.0	8.5	4.5
9	1	1	76.0	3.807	7.5	6.0	3.0	8.0	7.0	8.5	3.0
10	1	1	69.2	4.319	8.0	8.0	3.0	8.0	6.0	10.5	4.0
11	1	1	56.7	2.557	7.0	4.0	2.0	7.0	8.5	7.0	4.0
12	1	1	77.0	4.063	11.5	9.5	4.0	12.0	13.0	10.0	5.0
13	1	1	91.0	1.989	28.0	15.0	7.0	17.0	20.0	17.0	7.5
14	1	1	69.6	3.353	15.0	9.0	3.0	10.0	12.0	11.0	6.0
15	1	1	68.5	3.466	16.0	9.0	3.0	13.0	9.5	13.5	6.5
16	1	1	50.5	2.955	8.0	5.0	3.0	8.0	7.0	7.5	3.0
17	1	2	66.6	2.898	12.5	6.0	3.0	7.0	8.0	10.0	5.0
18	1	2	76.2	1.989	18.0	13.5	6.0	13.0	15.5	16.0	7.0
19	1	2	72.0	4.375	10.0	8.0	5.0	11.0	10.0	13.0	6.0
20	1	2	64.5	3.466	15.0	8.0	3.0	10.0	12.0	14.0	3.5
21	1	2	68.9	3.694	14.0	10.0	3.5	7.5	12.0	10.0	5.0
22	1	2	57.4	2.586	17.5	8.5	4.0	12.0	13.0	11.0	7.0
23	1	2	65.1	3.353	16.0	10.0	4.0	9.5	9.0	11.0	4.5
24	1	2	69.7	3.978	11.0	8.0	3.0	9.0	9.0	15.0	5.0
25	1	2	67.3	2.898	21.5	9.5	3.5	12.5	20.0	11.0	9.5
26	1	2	72.4	3.836	10.0	6.0	3.0	10.0	8.5	10.0	5.0
27	1	2	61.0	3.950	7.0	5.5	2.5	7.5	6.5	9.0	4.0
28	1	2	70.0	4.262	11.0	6.0	2.0	11.0	12.0	8.0	3.0
29	1	2	93.0	4.319	12.0	8.5	5.5	13.0	10.0	11.0	5.0
30	1	2	65.8	2.898	9.0	6.5	3.0	11.0	7.0	8.0	7.0
31	1	2	57.2	2.273	19.0	7.0	3.0	13.0	14.0	12.0	6.0
32	1	2	68.0	2.643	12.0	6.5	3.0	8.0	5.0	10.5	4.0
33	1	2	66.8	1.762	19.0	9.0	4.0	13.5	15.0	16.0	7.0
34	1	3	71.6	3.125	15.0	13.0	4.0	11.0	16.0	16.0	6.0
35	1	3	76.0	3.182	22.0	14.0	6.0	16.0	18.0	14.0	8.0
36	1	3	70.1	3.466	8.0	5.0	2.0	8.0	9.0	9.0	3.0
37	1	3	77.0	2.330	20.0	16.5	6.0	13.0	17.0	24.0	7.0
38	1	3	76.5	4.063	11.0	9.5	5.0	11.0	11.0	14.0	3.0
39	1	3	72.9	3.296	21.0	9.0	5.0	16.5	23.0	12.0	6.0
40	1	3	78.4	3.353	13.5	11.5	4.5	12.0	8.0	18.0	6.5
41	1	3	83.6	3.296	26.5	11.0	5.5	19.0	24.5	15.0	10.0
42	1	3	70.9	3.012	13.5	11.0	4.0	8.5	7.0	11.5	5.0
43	1	3	76.5	3.154	20.0	12.0	5.5	16.0	17.5	15.5	7.5
44	1	3	69.0	4.262	9.0	4.0	3.0	8.0	8.0	8.0	3.0

Measurements (Continued)

Sub-Ject	Group	Sub-Group	Weight (kg)	U-Wei. (kg)	SKINFOLDS (mm) ABD	Tri.	Bic.	Back	Iliac	Thi.	Che.
45	1	3	66.1	3.694	15.0	8.0	2.0	8.0	9.0	9.0	4.0
46	1	3	62.0	2.671	14.0	7.0	3.0	9.0	9.0	9.0	6.0
47	1	4	67.6	2.898	14.0	10.0	3.0	11.0	9.0	8.0	5.0
48	1	4	66.0	2.898	18.0	8.0	3.5	11.0	12.0	12.0	7.0
49	1	4	76.0	3.182	15.0	10.0	3.0	14.0	16.0	16.0	6.0
50	1	4	41.0	3.069	6.0	3.0	1.5	6.5	4.0	4.0	1.5
51	1	4	67.0	4.039	17.0	9.0	4.0	18.0	15.0	9.0	4.0
52	1	4	74.5	3.466	16.0	12.0	5.5	13.0	11.0	11.5	7.5
53	1	4	71.1	3.125	11.0	6.5	3.5	10.0	8.5	9.0	5.0
54	1	4	57.2	2.103	16.0	5.0	3.0	8.5	7.5	6.0	6.0
55	1	4	84.4	3.950	20.0	10.0	5.0	14.0	16.0	14.5	7.0
56	1	4	49.0	2.643	7.0	5.5	3.0	7.5	9.0	6.5	5.0
57	1	4	77.5	3.438	14.0	6.0	4.0	11.0	10.0	12.0	5.0
58	1	5	64.6	3.353	9.0	4.0	2.5	6.5	7.0	5.0	3.0
59	1	5	76.0	3.466	13.0	7.5	4.0	9.0	10.0	11.0	4.5
60	1	5	88.8	1.080	28.0	17.0	6.5	19.0	28.0	18.0	13.0
61	1	5	67.0	3.609	11.0	11.0	5.0	12.5	11.5	13.5	5.0
62	1	5	64.4	2.841	16.0	10.5	5.0	10.0	13.5	16.5	7.0
63	1	5	64.6	3.182	14.5	11.5	5.0	13.5	13.5	16.5	6.5
64	1	5	70.2	3.353	16.0	6.0	3.0	13.0	15.0	6.0	7.5
65	1	5	63.7	1.535	7.5	8.5	3.0	10.0	6.5	13.0	4.0
66	1	5	70.2	3.580	10.0	7.0	3.5	11.0	8.5	10.0	5.5
67	1	5	88.0	3.921	22.0	12.0	5.0	16.0	17.0	16.0	7.0
68	1	5	66.5	2.671	17.0	8.5	5.0	13.0	16.0	9.0	5.0
69	1	5	62.0	3.182	15.0	9.0	3.5	9.0	12.5	11.0	4.0
70	1	5	67.0	3.063	16.0	4.5	3.0	9.0	11.0	6.5	5.0
71	1	6	60.0	3.353	7.0	6.0	3.0	7.0	6.0	13.5	4.0
72	1	6	60.3	2.955	7.0	3.0	2.0	7.0	4.0	6.0	2.5
73	1	6	68.0	3.750	10.0	9.5	4.0	11.5	10.5	15.0	5.0
74	1	6	61.3	2.671	10.0	5.5	3.0	8.0	7.5	11.0	4.0
75	1	6	57.5	3.466	13.0	5.0	2.5	8.0	11.0	6.0	5.5
76	1	6	56.0	2.838	10.5	8.0	3.5	9.0	11.5	11.0	5.0
77	1	6	73.7	3.807	16.5	11.0	5.0	10.0	16.0	16.5	8.0
78	1	6	61.0	2.614	8.5	4.5	2.0	7.0	5.0	7.0	3.0
79	1	6	59.0	2.586	11.0	8.0	3.0	9.0	12.5	8.5	3.0
80	1	7	60.0	2.557	17.5	10.5	3.5	11.0	12.0	12.5	5.0
81	1	7	70.5	2.557	16.0	11.0	3.0	12.0	9.5	13.0	7.0
82	1	7	67.2	1.989	18.0	7.0	3.0	9.5	10.0	11.0	5.0
83	1	7	68.6	3.353	9.0	13.0	4.0	11.0	8.0	17.0	4.5
84	1	7	84.5	2.898	19.0	10.5	4.0	10.0	17.0	13.0	6.0
85	2	-	60.9	--	7.0	5.0	4.0	8.0	5.0	7.0	5.0
86	2	-	53.8	--	10.0	8.5	4.0	8.0	6.0	9.5	5.0
87	2	-	63.2	--	10.0	6.0	4.0	10.0	9.0	7.0	5.0
88	2	-	65.9	--	13.0	11.0	4.0	9.0	7.0	16.0	6.0
89	2	-	61.1	--	11.0	6.0	2.0	9.0	12.0	6.0	6.0
90	2	-	59.2	--	7.0	5.5	3.0	7.0	4.0	7.0	3.0
91	2	-	64.8	--	14.0	9.0	4.0	12.5	13.0	8.0	5.0
92	2	-	70.8	--	10.0	5.0	3.0	7.0	10.0	11.5	5.0

Measurements (Continued)

Subject	Group	Sub-Group	Weight (kg)	U-Wei. (kg)	SKINFOLDS (mm) ABD	Tri.	Bic.	Back	Iliac	Thi.	Che.
93	2	-	63.0	--	11.0	6.0	4.0	11.0	10.0	8.0	6.0
94	2	-	51.0	--	6.5	5.0	3.0	7.0	6.0	13.0	4.0
95	2	-	71.2	--	12.0	5.0	4.0	7.0	8.0	8.0	6.0
96	2	-	74.6	--	22.0	11.0	4.0	15.0	18.0	10.0	8.0
97	2	-	68.8	--	14.0	8.0	5.0	8.5	12.0	10.0	5.0
98	2	-	54.8	--	12.0	7.0	4.0	15.0	13.0	9.0	4.5
99	2	-	62.1	--	8.0	7.0	3.0	6.5	7.0	5.0	4.0
100	2	-	70.3	--	28.0	20.0	9.0	19.0	25.0	19.0	20.0
101	2	-	60.2	--	14.0	9.0	6.0	13.0	14.0	7.0	12.5
102	2	-	68.0	--	7.0	8.0	3.0	8.0	8.0	9.0	3.0
103	2	-	79.4	--	20.0	17.0	8.0	20.0	21.0	19.0	13.0
104	2	-	58.7	--	11.0	6.0	3.0	11.0	7.0	9.0	5.0
105	2	-	61.8	--	8.0	5.0	2.0	9.0	10.0	6.0	4.0
106	2	-	64.9	--	11.0	12.0	3.0	13.0	12.5	19.0	6.0
107	2	-	62.1	--	11.0	8.0	4.0	9.0	8.0	14.0	5.0
108	2	-	67.5	--	12.0	8.0	4.0	8.0	9.0	12.0	6.0
109	2	-	49.0	--	8.0	5.0	3.0	7.0	6.0	10.0	3.0
110	2	-	68.1	--	6.5	7.0	3.0	8.0	5.0	10.0	3.0
111	2	-	62.5	--	8.0	7.0	4.0	7.0	7.0	12.0	3.5
112	2	-	56.8	--	8.0	4.0	3.0	7.0	5.0	7.0	3.5
113	2	-	65.4	--	11.0	8.0	3.0	7.0	9.0	10.0	4.0
114	2	-	65.0	--	13.0	6.0	3.0	9.0	8.5	12.0	5.0
115	2	-	56.0	--	8.0	3.0	9.0	7.0	9.0	15.0	6.0
116	2	-	58.5	--	8.0	6.0	2.5	6.0	5.0	10.0	4.0
117	2	-	60.0	--	8.0	9.0	3.5	6.5	6.0	19.0	4.0
118	2	-	62.3	--	20.0	10.0	5.0	14.0	14.0	11.0	10.0
119	2	-	73.1	--	7.0	7.0	3.5	9.0	5.0	10.0	4.0
120	2	-	64.8	--	7.5	7.5	3.5	12.0	8.0	9.0	4.0
121	2	-	66.7	--	24.0	16.0	7.0	14.5	16.0	17.5	9.0
122	2	-	66.6	--	12.0	11.0	3.0	11.0	9.0	5.0	3.6
123	2	-	66.0	--	9.5	6.0	3.0	9.0	9.0	9.0	5.0
124	2	-	52.6	--	10.0	9.5	5.5	10.0	7.0	12.0	6.0
125	2	-	68.4	--	21.0	9.0	4.5	11.0	15.0	15.0	7.0
126	2	-	59.5	--	11.0	6.0	3.0	9.0	8.0	11.0	5.0
127	2	-	78.8	--	12.0	7.5	5.0	11.0	15.0	16.0	9.0
128	2	-	64.1	--	7.0	7.0	4.0	7.5	8.0	8.5	4.5
129	2	-	79.1	--	23.0	17.0	8.0	16.0	26.0	21.0	17.0
130	2	-	55.2	--	8.0	7.0	4.0	8.0	6.5	10.0	5.0
131	2	-	70.6	--	11.0	8.0	5.0	9.0	10.0	13.0	7.0
132	2	-	69.8	--	15.0	7.0	3.5	10.0	9.0	9.0	4.5
133	2	-	54.9	--	7.0	6.0	3.0	8.0	6.0	8.0	3.5
134	2	-	55.6	--	17.0	8.5	3.5	10.0	16.5	11.0	7.5
135	3	-	56.0	--	5.0	6.0	3.0	6.0	5.0	5.0	3.0
136	3	-	50.5	--	8.0	7.0	3.0	8.0	6.0	7.0	3.0
137	3	-	65.0	--	12.0	11.0	4.0	8.0	11.0	14.0	6.0
138	3	-	65.6	--	12.0	11.0	4.0	8.0	11.0	17.0	3.0
139	3	-	55.2	--	7.0	6.5	3.0	7.0	5.0	8.0	2.0

Measurements (Continued)

Sub-ject	Group	Sub-Group	Weight (kg)	U-Wei. (kg)	SKINFOLDS (mm) ABD	Tri.	Bic.	Back	Iliac	Thi.	Che.
140	3	-	72.6	--	28.0	12.0	8.0	14.0	19.0	21.0	8.0
141	3	-	65.4	--	13.0	8.0	5.0	13.0	8.5	8.0	6.0
142	3	-	60.5	--	10.0	6.5	3.0	8.0	11.0	7.0	4.0
143	3	-	60.8	--	10.0	12.0	4.0	8.0	7.0	13.0	3.0
144	3	-	67.0	--	8.0	7.0	3.0	6.0	6.0	11.0	3.0
145	3	-	54.0	--	8.0	6.0	3.0	5.0	6.0	9.0	3.0
146	3	-	80.3	--	18.0	12.0	7.0	14.0	16.0	17.0	8.0
147	3	-	60.8	--	10.0	6.0	3.0	8.0	8.0	7.0	4.0
148	3	-	71.1	--	12.0	12.5	4.0	11.0	8.0	14.0	5.0
149	3	-	60.0	--	8.0	7.0	2.5	8.0	7.0	7.0	4.0
150	3	-	51.2	--	6.5	4.0	3.0	6.0	4.0	5.0	4.0
151	3	-	68.4	--	17.0	9.0	5.0	13.0	19.0	11.0	8.0
152	3	-	59.5	--	6.0	5.0	3.0	7.5	6.0	8.0	4.0
153	3	-	65.0	--	11.0	3.0	5.0	8.0	9.0	10.0	5.0
154	3	-	55.6	--	7.5	11.0	4.0	8.0	6.0	18.0	6.0
155	3	-	55.8	--	12.0	8.0	5.5	7.0	8.0	11.0	6.0
156	3	-	58.3	--	9.0	6.5	5.0	8.0	9.0	10.0	4.0
157	3	-	54.0	--	10.0	10.0	5.0	6.0	8.0	13.0	5.0
158	3	-	64.3	--	18.0	12.0	4.5	9.0	14.0	13.0	7.0
159	3	-	53.8	--	6.0	4.0	2.0	7.0	5.0	4.0	2.0
160	3	-	53.9	--	10.0	12.0	4.0	10.0	11.0	9.0	7.0
161	3	-	70.0	--	15.0	11.0	6.0	9.0	11.0	14.0	5.0
162	3	-	49.8	--	11.0	8.0	3.0	7.0	10.0	9.0	4.0
163	3	-	60.8	--	12.0	8.5	3.0	10.0	7.5	11.0	5.0
164	3	-	61.2	--	6.0	7.0	2.5	6.0	5.0	11.0	3.0
165	3	-	63.3	--	17.0	9.0	6.0	8.0	17.0	12.0	6.0
166	3	-	62.8	--	24.0	10.0	5.0	13.0	22.0	8.0	6.0
167	3	-	61.0	--	15.0	7.0	3.0	10.0	11.0	9.0	5.0
168	3	-	73.2	--	21.0	14.0	6.0	14.0	18.0	20.0	11.0
169	3	-	64.3	--	13.0	9.0	4.0	8.0	8.0	13.0	6.0
170	3	-	63.0	--	15.0	5.0	2.0	14.0	9.5	7.5	5.0
171	3	-	55.0	--	9.0	8.0	3.5	8.0	7.0	8.0	6.0
172	3	-	54.2	--	12.0	8.0	4.0	9.0	14.0	15.0	6.0
173	3	-	62.6	--	7.5	7.0	4.0	10.0	7.0	13.0	5.0
174	3	-	62.4	--	13.0	13.0	5.0	10.0	7.0	14.0	6.0
175	3	-	61.2	--	10.0	8.0	5.0	7.0	6.5	8.0	7.0
176	3	-	76.1	--	32.0	20.0	13.0	18.0	22.0	24.0	9.0
177	3	-	62.3	--	8.0	6.0	4.0	8.0	5.0	7.0	3.0
178	3	-	76.0	--	23.0	10.5	4.5	12.0	16.0	12.0	9.0
179	3	-	57.0	--	6.0	5.0	2.5	7.0	4.0	9.0	4.0
180	3	-	61.0	--	11.0	7.0	3.0	8.0	7.0	9.0	4.0
181	3	-	56.8	--	6.0	4.0	2.0	6.0	4.0	6.5	3.0
182	3	-	61.9	--	13.0	8.0	2.5	5.0	9.0	11.0	4.0
183	3	-	51.0	--	5.0	5.0	2.5	5.0	3.5	6.0	3.0
184	3	-	54.0	--	8.0	4.0	3.0	6.0	5.0	6.0	3.5

2

VITA

Gazanfer Dogu

Candidate for the Degree

Doctor of Education

Thesis: DEVELOPMENT OF AN EQUATION TO PREDICT THE PERCENT BODY FAT OF 18 - 25 YEAR OLD TURKISH MALES THROUGH SKINFOLD TESTING

Major Field: Higher Education

Minor Field: Health, Physical Education and Recreation

Biographical:

Personal Data: Born in Ankara, Turkey, May 25, 1953, the son of Mrs. Hayriye and Mr. Yasar Dogu.

Education: Graduated from Cumhuriyet High School, Ankara, in 1971; studied for three semesters in the undergraduate program at Gazi Institute, Ankara in Physical Education; received a scholarship from the Turkish Government to study abroad in Physical Education and Recreation. After studying German for one year in the Goethe-Institute in Germany, went to Oklahoma State University and received the Bachelor of Science degree in Secondary Education in 1979; received Master of Science degree in Physical Education from Oklahoma State University in 1981; completed requirements for the Doctor of Education degree at Oklahoma State University in May, 1984.

Professional Experience: Organized and chaired the University's International Student Olympics program (1978-1982). Worked as a coach and soccer specialist for five consequent summers in the National Youth Sports Camp for Under-priviledged Children at Oklahoma State University (1979-1983). President of the Oklahoma State University Soccer Club (1979-1983), and Chairman of the organizing committee of Big Eight Soccer Tournament in Stillwater, Oklahoma, 1982. Worked (1979-1981) as the evening student manager of the Colvin Physical Education and Recreation Center. In 1982 became Manager of the new addition to the recreation facilities (Colvin Center-Annex) at Oklahoma State University.