PREDICTION OF BODY DENSITY

IN PRE-ADOLESCENT GIRLS

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CHAPTER I

THE RESEARCH PROBLEM

Significance of the Study

Obesity has reached epidemic proportions in the United States with conservative estimates concluding that one third of the adult American population is overfat, including ten million school age children.[1] Childhood obesity is particularly alarming because of its potential effect on our future adult generation. Mayer[2] has made a strong case in describing the obese as a minority group which suffers from prejudice and discrimination. He has shown that the obese frequently have feelings of inferiority and self blame imposed by a society with hostile attitudes toward them. One rather shocking statistic in a study by Canning and Mayer[3] found that obese girls had only one-third as much chance of being accepted into a prestige college, the college of her choice, or any college. Obese boys had two-thirds as much chance of being admitted to a prestige college. Mayer also found that obese women have a decreased likelihood of advancing socially through marriage.[4] In addition to the sociological stigma attached to obesity it can also have eventual negative effects physiologically including the disturbance of normal bodily functions, an increased risk of developing certain diseases and detrimental effects on established diseases.[5]

According to one theory, obesity is divided into two categories. Jules Hirsch[6] has hypothesized that obesity can be classified according to relative number and size of fat cells. In one type of obesity the patient has too many fat cells and would be said to be suffering from hyperplastic obesity, in the other type the patient has fat cells which are too large, a condition called hypertrophic obesity. It is obvious that hyperplastic obesity would be the most serious since it could also be compounded by hypertrophic obesity. In weight reduction, cell number is effected very little with almost all reduction taking place in actual cell size. Hyperplastic obesity is almost invariably incurred during childhood which almost certainly predestines those that were obese as children to remain obese as adults. According to Dr. Hirsch[7] the critical periods in a child's life which determine whether he will be obese as an adult are the last trimester of pregnancy, the first three years of life and adolescence.

Bearing in mind the above theory it is the researcher's purpose in this study to aid in the reduction of childhood obesity by developing a regression equation of anthropometric measures which can be used as a predictor for determining body density and percent fat in preadolescent girls. By helping to identify those with potential tendencies toward obesity, steps can be taken to reduce the extent of hyperplastic obesity which might be incurred during adolescence if it is gone unheeded or brushed off with the thought that the child will eventually grow out of the overweight stage. The AAPHER committee[8] on the revision of the AAPHER Youth Fitness Test strongly endorses the concept of early prevention of overfatness rather than its correction in later life and calls for the development of a regression equation specific to school age children.

Statement of Purpose

The purpose of this study was to develop a regression equation to predict body density in preadolescent girls using anthropometric measures as predictors.

Assumptions

1. All instruments in the study were calibrated as of September, 1977. The researcher assumed this calibration was still in effect at the time of testing.
2. The researcher assumed that she was free from any overt experimental bias. The researcher had no preconceived ideas about which measures would have the highest correlation to actual body density.

Delimitations

The following are delimitations to the study:

1. Subjects were taken from among the fifteen sections of fifth grade at Sooner Elementary in Jenks, Oklahoma.
2. The number of subjects totaled fifty-one.
3. The subjects were all female.
4. Anthropometric measures were limited to eight skinfold, eleven girth, and seven diameter measures.

Limitations

The following limitations were beyond the researcher's control.

1. Subjects were asked not to eat prior to underwater weighing but were on their honor.
2. Subjects were on the average ten years old and their ability to follow instructions on the tests varied.
3. Environmental factors may have effected the results of any of the tests.
4. The formulas used for converting density to percent body fat were developed for adults and may not be entirely accurate for children. The researcher found no formulas established for use with children.

Definition of Terms

The following are terms specific to this study:

1. Anthropometric Measures--skinfold, girth, and general body diameters.
2. Body Density--weight of the body underwater corrected for residual volume and gastrointestinal air (gms./ml.).
3. Lean Body Weight--weight in air less total percent body fat.
4. Percent Body Fat--percent of the body which is fat.
5. Residual Volume--air left in lungs after maximal exhalation.
6. Vital Capacity--maximal expiration of air after maximal inspiration.

FOOTNOTES

[1]B. Don Franks and others, "A Position Paper on Physical Fitness," AAPHER (1976), p. 14.

[2]Ibid., p. 19.

[3]Ibid., p. 20.

[4]Ibid.

[5]Ibid., p. 14.

[6]Myron Winich, M.D., "Childhood Obesity", Nutrition Today (May/ June, 1974), p. 7.

[7]Ibid., p. 8.

[8]B. Don Franks, p. 22.

CHAPTER II

REVIEW OF RELATED LITERATURE

Anthropometric Studies Done on Children

The researcher first searched the literature to find any studies directly relating to anthropometric studies done on children since that was the emphasis of the study. Relatively little information was available in this area. Charles Corbin and Philip Pletcher[1] studied the caloric intake and physical activity patterns of fifty fifth grade students to determine the relative contributions of diet and physical inactivity in the development of obesity. On the basis of tricep skinfold measurements, the subjects were divided into four groups or levels of obesity. Seven-day diet recall records were then obtained with the cooperation of the children's parents. Activity patterns were studied by filming the subjects during games of high and low organization and during free play. Indexes of the duration and intensity of activity were derived from the film analysis. The caloric intake and physical activity patterns of the four groups were compared. Using the combined scores for all groups, correlation coefficients were computed to determine the relationship between 1) skinfold measures and total caloric intake, 2) skinfold measures and activity patterns, and 3) total caloric intake and activity patterns. The relative inactivity of the obese children and the relatively similar diets of all children regardless of body fat, as well as the significant negative relationship between activity indexes and body fat tended to support the contention that inactivity may be as important or more important than excessive caloric intake in the development and maintenance of childhood obesity.

Charles Corbin[2] also studied 1,176 elementary school children measuring tricep and subscapular skinfolds to determine the amount of fat possessed by the child. He noted that even considering the amount of fat allowed was increased for each year, from younger ages to older ages, the least number of obese children was at age seven for boys where five percent were classified as obese. In excess of 25 percent of the girls at age ten were classified as obese. At age eleven, 16 percent of the boys were classified as obese. Girls possessed a relatively higher amount of fat when compared with boys.

Felix P. Heald[3] studied the obese adolescent. He found that during adolescence, boys increase their height by twenty percent and almost double their body mass. There is also a normal deposition of fat especially in girls. Obese teenagers were found to eat when bored rather than when hungry, and although they were usually taller than their peers, they tended to be shorter as adults. They also commenced puberty earlier.

Dr. Glenn Friedman[4] in a conference report stated that the time to begin prevention of atherosclerosis and obesity is in childhood because that is when patterns of living that lead to these things begin. He found that atherosclerosis did develop in the pediatric age group and was reversible at that stage of life.

In a study done on sex difference in body composition by Hakan Ljunggren[5] it was stated that at three to seven years there is a difference between boys and girls regarding the thickness of subcutaneous fat. Body mass is more dense in nine year old boys than in girls of equal age. At age two to three the basal metabolism is higher in boys than in girls of corresponding body size.

Procedure for Underwater Weighing

Since there was such a limited amount of research available on children and body compositional studies, the researcher chose to base the present study on those done in the determination of percent body fat in other age categories such as adult men and women. Underwater weighing was generally included as a procedure in those studies so the following is a review of the literature describing that procedure.

David Clark[6] in his textbook on exercise physiology describes one technique of underwater weighing. He states that a rather precise estimate of body composition can be obtained by applying Archimedes principle of body density: when a body is immersed in water it is acted upon by a buoyant force, such that the loss of weight is equal to the weight of the displaced fluid. In actual practice this requires an individual to be weighed underwater having fully exhaled, to find the loss of weight in water. Certain corrections must be made, one for the density of the water at that particular water temperature, another for the residual volume of air left in the lungs at the time the underwater weight was taken. The residual volume correction is important because air left in the lungs exerts a buoyant effect upon the body when it is submerged and it would readily distort the estimates of body fat unless taken into account. There is also a certain amount of gas remains trapped in the gastrointestinal tract, about 100 ml., which must be considered. He uses the following formula in determining body density, where Wa=weight in air, Ww=weight in water, Dw=density of water at

$$D = \frac{Wa}{\frac{(Wa - Ww)}{Dw} - (RV + 100 \text{ ml.})}$$

water temperature, and RV=residual volume. From these calculations, a low value would indicate a relatively large proportion of body fat and conversely a high value would indicate a small proportion of body fat. In order to calculate the percent of fat from knowledge of the body density, the following formula is satisfactory.

$$\text{percent fat} = 100 \frac{4.570}{\text{body density}} - 4.142$$

Herbert deVries[7] in his exercise physiology text described the procedure of underwater weighing as follows. The subject is completely submerged, then the individual's specific gravity is calculated where

$$\text{specific gravity} = \frac{\text{dry weight}}{\text{loss of weight in water}} .$$

This value must be corrected for residual lung volume which is determined by a nitrogen washout of the lungs. With the corrected specific gravity, one may enter tables to arrive at the percent of body fat. The normal percent fat for young men has been estimated from ten to fourteen percent, and the normal value for young women is slightly higher.

Behnke and Wilmore[8] state that one of the most accurate and widely used methods for assessing body volume--hydrostatic weighing--utilizes Archimedes basic physical principle that a body immersed in a fluid is acted upon by a buoyancy force, which is evidenced by a loss of weight equal to the weight of the displaced fluid. When an individual is weighed underwater while totally submerged, the total body volume is equal to his loss of weight in water corrected for the density of the water (Dw) corresponding to the water temperature at the time of the weighing. Body volume is derived from the equation:

$$BV = \frac{Wa - Ww}{Dw}$$

where Wa and Ww are the individual's weight in air and water respectively. They also correct for residual volume and gastrointestinal air (100 ml.) The actual weighing of the individual underwater is easily accomplished by having the individual sit in a chair supported by a scale in a closed body of water. At least ten successive trials should be undertaken and the selection of the best weight is determined by the following criterion. 1) The highest obtained weight if it is observed more than twice. 2) The second highest weight if it is observed more than once and if the first criterion is not attained. 3) The third highest weight if neither the first or second criterion are attained. Percent fat can in turn be determined by any of the following equations:

Rathburn and Pace percent body fat = $\left(\frac{5.548}{\text{specific gravity}} - 5.044\right) \times 100$

Brozek percent body fat = $\left(\frac{4.570}{\text{density}} - 4.142\right) \times 100$

Siri percent body fat = $\left(\frac{4.950}{\text{density}} - 4.500\right) \times 100$

Frank Katch[9] conducted a study to determine the minimum number of trials necessary to establish "true" underwater weight during body density measurements on 86 college females. Nine to ten trials of underwater weight were recorded for each subject. The results showed a significant upward trend of a curved nature during successive trials of weighing. As subjects became accustomed to making a maximum expiration while submerged underwater, the amount of air expired increased progressively between trials one and ten. Thus underwater weight increased during consecutive trials which affected body density values by .001-.003 density units. Similar changes have been reported by others and contributed to physical training and conditioning programs. In 42 percent of the subjects, highest underwater weight was observed during the first five trials. The magnitude of error associated with these trials was considerably higher than for the last several trials. This was due to an 85 percent reduction in within-individual variability. This represented a large increase in the consistency of the measurement. In order to obtain the most representative underwater weight for an individual, 9 to 10 trials were necessary. The average value calculated from the last three trials was used to establish "true" underwater weight.

Determination of Residual Lung Volume

While researching underwater weighing procedure it became evident that the residual lung volume was a necessary factor to be included. The following is literature on determination of residual lung volume.

Jack Wilmore[10] has attempted to develop a method for obtaining an indirect estimate of residual lung volume which is valid and reproducible and which minimizes the time needed for duplicate determinations on a single subject. The proposed method is basically a modification of the closed-circuit oxygen-dilution method reported by Lundsgaard and Van Slyke in 1918. The subject places his mouth over a mouthpiece attached to a Collins 9-liter respirometer. After 3-4 normal respirations with the breathing valve turned to outside air, the subject is instructed to inhale deeply and then exhale as fully as possible. At maximal expiration the breathing valve is turned to connect the subject with the spirometer circuit and the nitrogen reading at the end of the expiration is assumed to be the initial alveolar nitrogen concentration. The subject then inspires and expires at two-thirds of maximum once every three seconds. When equilibrium is reached the subject takes a maximum inhalation followed by maximal exhalation. Final nitrogen concentration is then recorded. This method was compared with the open-circuit method where nitrogen is "washed out" of the lungs during a specified period of oxygen breathing. On a sample of 20 normal and healthy subjects the intercorrelation was r=0.958 and the mean difference was only 26 ml. The reproducibility of this method was established on a sample of 195 males with a test-retest correlation of 0.993 and a standard error of measurement of 28 ml. and on a sample of 102 females with a correlation of 0.987 and a standard error of measurement of 30 ml. The proposed method, in addition to having a high degree of validity and reproducibility provides a duplicate determination of the residual volume for any one subject within approximately 8-10 minutes, representing a two to sixfold reduction in the total testing time when compared with existing methods.

According to Frank Katch's[11] study, individual changes in the body density of 62 young men who participated in a ten week physical conditioning program were found to be more closely related to changes in residual lung volume than to changes in body weight or underwater weight. It was concluded that if an assumed constant value of residual volume is used to compute density, then observed changes in body density for an individual subject due to an experimental treatment such as physical conditioning may be masked by large changes in residual lung volume.

Wilmore[12] also attempted to evaluate the extent of the potential error inherent in using either a constant average value or a predicted value of residual volume as opposed to the actual measurement of residual volume in the calculation of body density, percent body fat and lean body weight. Measurements of underwater weight, residual volume and vital capacity were recorded from 69 male and 128 female college age subjects. The results indicate a very close agreement between the actual values for density, percent fat, and lean body weight, and those obtained through either an estimated or a constant residual volume. There is, however, enough individual variation to indicate the necessity for using the actual measured residual volume for research purposes when absolute accuracy is essential.

Anthropometric Measurement

The researcher intended to use certain anthropometric measures as independent variables in the development of the regression equation for prediction of body density. The following is literature concerning actual procedure for anthropometric measurement.

Behnke and Wilmore[13] state that the body can be described quite accurately through a series of measurements of the external morphology of the body. These measurements are divided into three categories: bone and general body diameters, girths or circumferences, and skinfold thicknesses.

Diameters are measured using bone to bone contact with the soft tissue compressed. They are typically measured with a broad or narrow blade anthropometer and can include the following sites: head length, head width, biacromial diameter, bideltoid diameter, chest width, bi-iliac diameter, bitrochanteric diameter, knee, ankle, elbow, wrist, arm span, hand length, foot length, leg length, trunk length and stature.

Circumference measures are more difficult to obtain accurately because of the compression of soft tissue. The Gulick tape was developed with a spring-loaded handle allowing for constant tension through out all measurement sites to aid in accuracy. Circumference sites include: head, neck, shoulders, chest, abdomen, waist, hips, thigh, knee, calf, ankle, deltoid, bicep flexed, bicep extended, forearm, and wrist.

The assessment of subcutaneous body fat is accomplished by using a special calipers which are calibrated to provide a constant tension throughout their range of motion. The calipers actually measure the thickness of a double layer of skin and the interposed layer of fat. There are only slight differences between individuals in the thickness of skin, so the resulting value is an indirect estimate of individual differences in the thickness of subcutaneous fat. Skinfold sites can include: chin, chest, scapula, triceps, midaxilla, waist, suprailiac, abdominal, thigh, knee, and calf.

Clark[14] states that the most popular and most widely used technique for body density determination is the one that involves skinfold measures. It is based on the proposition that the extent of adiposity can be estimated by measuring the thickness of the double layer of skinfolds at various sites on the body. Not all of the adipose tissue resides in the subcutaneous areas, but it is usually accepted that the skinfold may be used as an index of total body fat. Specially designed calipers are employed with constant spring tension, the measures are all obtained in millimeters, and the right side of the body is used in each instance.

Prediction of Body Density

The following literature includes a group of studies done on various population groups using anthropometric measures as predictors for body density.

Katch and Michael[15] predicted body density from skinfold and girth measurements of college females at the University of California, Santa Barbara. 64 subjects were weighed underwater to determine body density. Six subcutaneous skin-fold measurements, four girth measurements, and four bone diameters were taken on the subjects. The mean body density was 1.049 g/ml, which corresponded to 21.5% by weight of fat. The skinfold which showed the highest correlation with density in a stepwise multiple regression analysis was the tricep skinfold (-0.59), while the best single girth measurement was the buttock (-0.52). The highest multiple correlation with density was from the iliac, tricep, and scapula skinfold, and buttock, abdomen, and arm girths (0.72). Using only four measurements, tricep and scapula skinfold and buttock and arm girths, resulted in a correlation of 0.70.

Sloan[16] estimated body fat in young men in 1967. The body density of 50 healthy, young, white men was determined by underwater weighing, allowance being made for the pulmonary residual volume determined by the open-circuit nitrogen dilution method. Skinfold thickness was measured with the MNL caliper at each of seven sites. The skinfold measurement over the front of the thigh had the highest individual correlation with body density and the highest multiple correlation of two skinfolds with density was given for prediction of body density from those skinfold measurements. The thickness of subcutaneous fat was measured with an ultrasonoscope at the same seven sites. Once again the measurement on the front of the thigh had the highest correlation with body density. The highest multiple correlation given by two ultrasonic measurements was from front of thigh and iliac crest.

Pollock[17] purposed to predict body density of young (18-22) and middle aged (40-55) men and to determine if generalized equations were appropriate to both populations. The independent variables included 7 skinfold, 11 girth, and 7 diameter measures, age, height, and weight. The dependent variable, body density, was determined by hydrostatic technique. Mean body density for young men was 1.068 g/ml. and percent fat 13.4; the values for middle aged subjects were 1.043 and 24 percent fat. Using multiple regression analysis, with the exception of girth measurements, the slopes of the regression were equal. However the intercepts were different. These results confirmed the need for different regression equations for the populations. The most accurate predictors for young men was two skinfold, four girth, and two diameter measures; two skinfold and three girth measures accurately predicted body density for middle aged men.

Pollock[18] studied body composition on 20 elite class runners. Findings supported the practice of using population specific equations and questioned the accuracy of predicting body density in a very lean population from equations developed from a normal population or athletic population with a different body type.

Wilmore and Behnke[19] investigated the validity of predicting body density and lean body weight from 54 anthropometric measurements in a sample of 133 college age males. The hydrostatic weighing technique was employed to evaluate body density, with residual lung volume being estimated by the nitrogen dilution technique. Siri's formula was used to estimate percent body fat, with the latter being used in the calculation of lean body weight. A regression analysis of the data indicated body density could be predicted from five anthropometric measurements with a multiple R=0.867 and a standard error of estimate of 0.0064 g/ml. Likewise, lean body weight could be predicted from five anthropometric measurements with a multiple R=0.958 and a standard error of estimate of 2.36 kg. The values for density, specific gravity, fat percentage, and lean body weight were also calculated from several predictive equations reported previously using the data from the present sample of subjects. The results indicated that maximum predictive accuracy is attained only when these equations are applied to population samples which are similar to those from the group which the original equations were derived.

Pollock, Laughridge, Coleman, Linnerud, and Jackson's[20] study was to predict the body density of young and middle aged women and to determine if the use of a greater variety of variables, particularly those for fat in the bust and hip regions, increases the predictability of body density. Body density determined by the hydrostatic technique (dependent variable) was obtained from 83 volunteer young women and 60 middle aged women ranging from 18-22 and 33-50 years of age respectively. Independent variables included 8 skinfold, 13 girth, and 7 diameter measures; age; height; weight; and bra and cup sizes. Mean body density for young women was 1.043 g/ml and percent fat, 24.8; 1.031 g/ml and 29.8 percent fat for middle aged subjects. Percent fat was calculated by the formula of Siri. Factor analysis was used to determine the dimensions measured by the independent variables as a function of age. A multiple regression model was used to develop predictions of body density from the independent variables. The best combination of four variables for predicting body density was skinfold thigh, skinfold suprailiac, diameter knee, and girth wrist (R=0.83) for young women and cup size, skinfold suprailiac, girth waist, and skinfold thigh (R=0.89) for middle aged women. The data showed that the highest predictions were found by using combinations of skinfold, girth and diameter variables; cup size was important only with the middle aged group. The data also supported the need for different regression equations for different age groups.

In a study done by Durnin and Rahaman[21] skinfold thickness and body density were measured on 105 young adult men and women, and 86 adolescent boys and girls. Subjects were of varying body build--thin, intermediate, plump--but very few were obese. Subjects were weighed underwater and measured at four skinfold sites (biceps, triceps, subscapular, suprailiac). Simple regression analysis, using body density as the dependent variable and the log value of the sum of the four skinfolds as the independent variable was carried out. The correlation coefficients between skinfold thicknesses and body density were in the region of -.80. The regression equation predicted body fat from skinfolds with an error of $\pm$ 3 and 3.5 percent.

Wilmore, Girandola, and Moody[22] evaluated the validity of a number of previously derived equations for estimating body density, specific gravity, body fat, and lean body weight from skinfolds or a combination of skinfolds or girths after a jogging type program. The subjects included 23 girls between 14 and 18 years of age and 55 men between 17 and 59 years of age. When compared to the underwater or hydrostatic weighing techniques, various prediction equations were found to be accurate with respect to their relative values, but their actual or absolute values were highly inconsistent. In addition, the actual changes in Db, fat and LBW were found to have only low-to-moderate correlations with the predicted changes. This suggests that the practice of using prediction equations to estimate actual changes in body composition parameters after physical training programs is basically unsound when used for research purposes.

Katch and Michael[23] did a densiometric validation of six skinfold formulas for predicting body density. In order to evaluate the variable and constant error of these skinfold prediction equations, 18 skinfold and girth measures were determined in 40 young males. The subjects were also weighed underwater to determine the criterion body density directly. The constant errors of prediction were very high, ranging from -10 to 122 percent. Validity coefficients ranged from r=.795 to .863; thus the predictive error of individual scores was 25 to 37 percent. In view of the large constant errors, the utility of these formulas for clinical application in estimating leanness and fatness was questionable. The relative ordering of individuals on the leanness-fatness scale could be accomplished more successfully, but the validity was moderate rather than high.

Summary

Relatively little literature was found relating directly to this study. The researcher found no studies predicting body density by anthropometric measure done on normal children. Various studies were reviewed concerning different aspects of the study including procedure on underwater weighing, residual volume testing and anthropometric measurement. Studies relating more directly to the study but involving mainly adult populations were also reviewed.

FOOTNOTES

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[22]Jack H. Wilmore, Robert N. Girandola, and Dorothy L. Moody, "Validity of Skinfold and Girth Assessment for Predicting Alterations in Body Composition," Journal of Applied Physiology 29:3 (1970), pp. 313-317.

[23]Frank Katch and Ernest Michael, "Densiometric Validation of Six Skinfold Formulas to Predict Body Density and Percent Fat of 17 Year Old Boys," Research Quarterly 40:4 (1969), pp. 712-716.

CHAPTER III

METHODS AND PROCEDURES

Organization of the Study

This study was undertaken to develop a predictive regression equation for determining body density in preadolescent girls using anthropometric measurements.

A random sample of female subjects from each fifth grade class in Sooner Elementary of Jenks, Oklahoma, was chosen. Only those that obtained parental permission were tested from among the random sample. This, of course diluted the randomness of the sample, but was unavoidable, since the testing required both parental permission and cooperation. The total number of subjects successfully tested was fifty-one.

Subjects were tested in three phases including anthropometric measurement, residual volume and vital capacity measurement, and hydrostatic weighing. Administration of the test took place between November 1, and December 17, 1977, with the hydrostatic weighing taking place on Saturday mornings to allow the subjects to be weighed before eating. Note: Three individuals were weighed underwater in the afternoon because of extenuating circumstances on the part of the subjects.

Source of Data

The data of this study was derived from the results of the anthropometric measures, the residual volume and vital capacity measures taken with the Ohio 842 Spirometer, and the actual body density determined by hydrostatic weighing.

Administration of Tests

Height, weight, date of test, and birthdate were recorded for each subject on a personal information sheet. The following procedures were used for each test.

Test One

Anthropometric measures were taken including the following:

1. Skinfolds
   a. Chest--over the lateral border of the pectoralis major, just medial to the axilla, fold running diagonally between the shoulder and the opposite hip.
   b. Midaxillary--vertical fold on the midaxillary line approximately at the level of the fifth rib.
   c. Triceps--midway between the acromion and olecranon processes on the posterior aspect of the arm, the arm held vertically, with the fold running parallel to the length of the arm.
   d. Abdominal--horizontal fold adjacent to the umbilicus.
   e. Suprailiac--vertical fold on the crest of the ilium at the midaxillary line.
   f. Thigh--vertical fold on the anterior aspect of the thigh midway between the hip and knee joints.
   g. Knee--vertical fold at the midpoint of the patella.

2. Girth Measures

a. Shoulder--laterally at the maximal protrusion of the deltoid muscles and anteriorly, at the articular prominence of the sternum and second rib.

b. Chest--nipple line at mid-tidal volume.

c. Abdominal--laterally at the level of the iliac crests, and anteriorly, at the umbilicus.

d. Waist--laterally, midway between the lowest lateral portion of the rib cage and the iliac crest, and anteriorly midway between the xyphoid process of the sternum and the umbilicus.

e. Gluteal--anteriorly, at the level of the symphysis pubis, and posteriorly, at the maximal protrusion of the gluteal muscles.

f. Thigh--just below the gluteal fold or maximal thigh girth.

g. Calf--maximal girth.

h. Ankle--minimal girth, superior to the malleoli.

i. Arm--maximal girth of the mid-arm when the elbow is locked in maximal extension with the underlying muscles fully contracted.

j. Forearm--maximal girth with the elbow extended and the hand supinated.

k. Wrist--minimal girth just distal to the styloid processes of the radius and ulna.

3. Diameter Measures

a. Shoulder--distance between the outermost protrusions of the shoulder with the anthropometer making only light contact with the skin.

b. Biacromial--distance between the most lateral projections of the acromial processes with the elbows next to the body.

c. Chest--arms abducted slightly for placement of the anthropometer at the level of the fifth to sixth ribs.

d. Bi-iliac--distance between the most lateral projection of the iliac crest.

e. Bitrochanteric--distance between the most lateral projections of the greater trochanters.

f. Knee--distance between the outermost projections of the tibial condyles.

g. Wrist--between the styloid processes of the radius and ulna.[1]

All measures were taken in a standing position and on the right side of the body. Skinfold measures were taken with a Harpenden skinfold caliper with a constant pressure of $10 g/mm^2$ and the mean of three replicate measures was recorded. Girth measures were taken with an anthropometric tape measure with a Gulick handle to insure even pressure. Diameters were measured with a broad blade anthropometer. All anthropometric data was measured and recorded to the nearest .5 mm, .5 cm, and .5 cm for skinfold, girth and diameter respectively.

Test Two

Residual volume was measured in a sitting position with an Ohio 842 Spirometer. The scores of two tests were averaged and the average score was included in the hydrostatic weighing formula. Vital capacity was also measured and recorded for each subject.

Test Three

Actual body density was determined by hydrostatic weighing. Each subject was measured in the hydrostatic weighing facilities at the Oral Roberts University Human Performance Laboratory. The subjects sat on a chair suspended from a Chatillion 15 kg scale in an enclosed 4 foot by 6 foot tank of water. After expelling all but residual lung volume the subject submerged and the underwater weight was recorded. 6-10 trials were taken on each subject and the highest consistent weight was recorded. Water temperature was recorded after each test.

Collection and Analysis of Data

The data was collected and analyzed as follows. Note: Computer analysis was done by the Oral Roberts University computer center.

1. Anthropometric measures were recorded for each subject on the sites previously listed.
2. Residual volumes were recorded after computer computation from raw data.
3. Vital capacity, forced expiratory volume, and forced expiratory volume in 3 seconds were recorded directly from the Ohio 842 Spirometer.
4. Body density determined by hydrostatic weighing were recorded after computer computation from raw data.
5. Percent fat determined from body density was calculated by computer.
6. Lean body weight determined from body density was calculated by computer.

7. Mean scores for all variables were calculated by computer.
8. Range of all scores was calculated by computer.
9. Standard deviation of all scores was calculated by computer.
10. Using the hydrostatically determined body density as a dependent variable all the anthropometric measures were used as independent variables in a multiple stepwise regression analysis used to isolate the independent variables that accounted for a significant proportion of body density variance and to develop regression equations for prediction of body density, percent fat and lean body weight.

Reliability of testors was determined as follows:

1. The researcher chose thirty students (fifth grade females) prior to the mass testing and did a test-retest reliability study on all anthropometric measures. A Pearson product-moment correlation was run on the data and correlations ranged from .92-.99 on skinfolds, .90-.99 on girth measures, and .95-.98 on diameter measures.
2. Technicians at the Oral Roberts University Human Performance Laboratory with proven reliability did the residual volume, vital capacity, and hydrostatic weighing.

FOOTNOTES

[1]Albert R. Behnke and Jack H. Wilmore, Evaluation and Regulation of Body Build and Composition (New Jersey, 1974), pp. 39-51.

CHAPTER IV

DISCUSSION OF RESULTS

The researcher tested fifty-one fifth grade female subjects to determine actual body density and to develop regression equations to predict body density, percent fat, and lean body weight. Twenty-six anthropometric measures were taken including eight skinfold, eleven girth, and seven diameter measures. Twenty-four of these measures were used in the actual computation along with height and weight. Residual volumes were measured with the Ohio 842 Spirometer and used to help compute actual body density determined by underwater weighing.

Table I records the mean age and physical characteristics of the subjects. The average subject was 128.2 months old, 56.25 inches tall, and weighed 74.2 pounds. Actual body density was 1.053 g/ml, percent fat using Brozek's formula for computation was 19.54 percent, and lean body weight was calculated to be 59.12 pounds. Age ranged from 121 months to 139 months and the standard deviation was 4 months. Height ranged from 49 inches to 63 inches; standard deviation was 2.94 inches. Weight ranged from 48.5 pounds to 121 pounds with the standard deviation at 11.73 pounds. Body density ranged from 1.008 g/ml to 1.084 g/ml with standard deviation at .0168. Percent fat ranged from 7.1to 38 percent with standard deviation at 6.689. Lean body weight ranged from 40.70 pounds to 72.6 pounds with the standard deviation 6.647.

TABLE I

AGE AND PHYSICAL CHARACTERISTICS OF SUBJECTS

VARIABLE	N	MEAN	STANDARD DEVIATION
AGE (months)	51	128.2	± 4.0
HEIGHT (in.)	51	56.25	± 2.94
WEIGHT (lbs.)	51	74.2	±11.73
BODY DENSITY (g/ml)	51	1.053	± 0.0168
**%BODY FAT (BROZEK)	51	19.54	± 6.689
LEAN BODY WEIGHT (BROZEK) (lbs.)	51	59.12	± 6.647

**%BODY FAT BROZEK-- $\left(\frac{4.570}{\text{density}} - 4.142 \right) \times 100$

Individual statistics on all measures are recorded in Tables IV-VII in the Appendix. There was a great deal of variability among the subjects especially in the area of height and weight with the smallest subject being 49 inches tall and weighing 48.5 pounds and the largest being 63 inches tall and weighing 121 pounds. This may account for the slightly higher standard error found in this study as compared to others done on adults. However, it is the researcher's subjective evaluation that this is a relatively "normal" distribution of size for an average fifth grade class. There was also an observable range of sexual development as would be expected in this age group.

Table II contains information on the correlation of height, weight, skinfold, girth, and diameter measures with density, percent fat, and lean body weight as well as means and standard deviations on the

TABLE II

COMPARISON OF HEIGHT, WEIGHT, SKINFOLDS, GIRTHS, & DIAMETERS WITH DENSITY, %FAT, AND LEAN WEIGHT

			CORRELATION		
VARIABLE	MEAN	S.D.	DENSITY	BROZEK %FAT	BROZEK LEAN WEIGHT
HEIGHT (in.)	56.25	± 2.94	-.28	.29	.75
WEIGHT (lbs.)	74.20	±11.73	-.71	.72	.80
SKINFOLDS (mm)					
CHEST	12.77	± 5.73	-.81	.82	.33
MIDAXILLARY	8.48	± 4.62	-.82	.84	.23
TRICEPS	15.09	± 5.33	-.77	.78	.29
SUBSCAPULAR	9.15	± 4.43	-.79	.80	.31
ABDOMINAL	15.87	± 6.99	-.82	.83	.36
SUPRAILIAC	15.01	± 7.55	-.85	.87	.32
THIGH	21.12	± 6.78	-.77	.78	.36
GIRTHS (cm)					
SHOULDER	80.76	± 5.05	-.49	.50	.77
CHEST	62.23	± 4.61	-.47	.49	.60
ABDOMINAL	60.76	± 6.50	-.73	.75	.46
WAIST	56.12	± 4.67	-.72	.74	.52
GLUTEAL	71.00	± 6.04	-.74	.76	.68
THIGH	40.24	± 3.76	-.62	.63	.64
ANKLE	18.24	± 1.31	-.45	.46	.63
ARM	19.51	± 1.92	-.66	.67	.56
FOREARM	18.82	± 1.31	-.59	.60	.63
WRIST	13.31	± 0.927	-.50	.51	.53
DIAMETERS (cm)					
SHOULDER	31.64	± 2.46	-.39	.40	.59
BIACROMIAL	24.21	± 1.64	-.12	.12	.55
CHEST	21.33	± 1.44	-.48	.49	.60
BITROCHANTER	24.00	± 1.75	-.58	.60	.76
BI-ILIAC	20.15	± 1.64	-.60	.61	.71
KNEE	8.61	± 0.557	-.46	.47	.70
WRIST	4.50	± 0.367	-.12	.14	.55

anthropometric measures.

Skinfold measures correlated highest with body density ranging from -.77 to -.85 with the suprailiac measure being the highest single predictor. Girth measures had slightly lower correlations for body density ranging from -.45 to -.74 with gluteal girth being the highest predictor. Diameter measures were lowest in correlation for density ranging from -.12 to -.60 with bi-iliac being the highest predictor. Percent body fat followed the same general pattern. Skinfolds correlated highest ranging from.78 to .87 with suprailiac as the highest individual predictor. Girths were second with correlations ranging from .46 to .76 with gluteal girth as the highest single predictor. Diameters ranged from .12 to .61 with bi-iliac as the highest predictor.

Lean body weight, as would be expected, correlated most highly with actual weight at .80. Skinfold correlation ranged from .23 to .36 with thigh and abdominal as the highest predictors. Girths proved to have the highest correlation ranging from .52 to .77 with the shoulder measure as the highest predictor. Diameters were second highest ranging from .55 to .76 with the bitrochanter diameter highest at .76.

Thigh skinfold was the largest skinfold at 21.12 mm. It was followed closely by abdominal at 15.87 mm, triceps at 15.09 and suprailiac at 15.01 mm. Midaxillary skinfold was lowest at 8.48. Shoulder girth was the largest at 80.76 cm. Shoulder diameter was also the largest at 31.64 cm. Wrist girth and diameter were smallest.

As would be expected from the individual measure correlation, skinfolds proved most significant in the actual regression equations developed. Table III shows the computer formulated multiple regression analysis of the anthropometric measurements relative to predicting

TABLE III

MULTIPLE REGRESSION ANALYSIS OF ANTHROPOMETRIC MEASUREMENTS RELATIVE TO PREDICTING BODY DENSITY, LEAN BODY WEIGHT AND PERCENT FAT

PREDICTED VARIABLE	ANTHROPOMETRIC MEASURE USED	NO. OF VARIABLES	MULTIPLE REGRESSION EQUATION	R	S.E.
Density g/ml	Skinfolds	3	.000785593 (sum of mid-axillary, abdominal, and suprailiac skin-folds) + 1.08479	.877	.008053
Lean Body Weight kg. Brozek formula used for %fat determination	Skinfolds Weight	4	.725769 (weight) - (26.2379) Log (sum of abdominal, scapular, and thigh skinfolds) + 48.2282	.89	3.0825
Percent Fat Brozek= (4.570 / density - 4.142) x 100	Skinfolds	3	.327403 (sum of mid-axillary, abdominal, and suprailiac skin-folds) + 6.65534	.88	3.306

R=Correlation S.E.=Standard Error

body density, lean body weight and percent fat.

The equation for predicting body density used three skinfold measures: midaxillary which correlated individually at-.82, abdominal, correlating at-.82, and suprailiac correlating at -.85. The actual equation is Body Density = .000785593 (sum of midaxillary, abdominal, and suprailiac skinfolds) + 1.08479. The multiple R was .877 with a standard error of .008053. In relation to other studies done on adults this appears to be a very good equation. Further validation will be necessary to prove just how accurate it will be.

Lean body weight prediction based on the Brozek formula for percent fat conversion from body density used four measures including weight correlating at .80 and the sum of three skinfolds; abdominal, subscapular, and thigh. The equation is Lean Body Weight = .725769 (weight) -(26.2379) Log (Sum of abdominal, subscapular, and thigh skinfolds) + 48.2282. Multiple R was .89 and the standard error 3.0825. The correlation is high but the standard error was slightly higher than desired possible due to the wide variability among the subjects.

The equation for percent fat based on Brozek's conversion formula utilized three skinfold measures; midaxillary correlating individually at .84, abdominal correlating at .83 and suprailiac correlating at .87. The regression equation is Percent Fat = .327403 (Sum of midaxillary, abdominal, and suprailiac skinfolds) + 6.65534. The multiple R was .88 with a standard error of 3.306. Correlation is high but the standard error is also slightly higher than desired again because of the wide variability of the subjects. It should be noted here that to the researcher's knowledge no cadaver studies have been done on children to determine a formula for converting body density to percent fat.

Brozek's formula was used as the best adult conversion formula.

One could question the use of three skinfolds as opposed to using only the suprailiac which correlates individually at .87. However, the researcher chose to use the three measure equation with its multiple R of .88 because of its lower standard error. The suprailiac measure alone had a 3.42 standard error as opposed to 3.306 on the three measure equation.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

After completing testing and computer analysis, the researcher devised the following formulas for predicting body density, lean body weight, and percent fat from anthropometric measures.

Body Density = .000785593 (sum of midaxillary, abdominal, and suprailiac skinfolds) + 1.08479.

Multiple R = .877

Standard Error = .008053

Lean Body Weight = .725769 (weight) - (26.2379) Log (sum of abdominal, subscapular, and thigh skinfolds) + 48.2282.

Multiple R = .89

Standard Error = 3.0825

Percent Fat = .327403 (sum of midaxillary, abdominal, and suprailiac skinfolds) + 6.65534.

Multiple R = .88

Standard Error = 3.306

With proper validation it is hoped that these prediction equations will be utilized to help identify those preadolescent girls with potential tendencies toward obesity. Identification of the problem of overfatness at an early age with subsequent efforts at correction could greatly aid in the reduction of adult obesity.

The researcher recommends that much more extensive testing be done in this area at ages below preadolescence and that a matching study be done on boys to develop an equation for them. The researcher conjectures that there is a difference significant enough between boys and girls at preadolesence to merit a study done only on boys, similar to this one done on girls. Childhood obesity is rampant in the United States and research done to aid in its prevention and correction is desperately needed.

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APPENDIX

TABLE IV

INDIVIDUAL MEASUREMENTS OF ALL SUBJECTS

SUBJECT	AGE IN MONTHS	HEIGHT IN INS.	WEIGHT IN LBS.	DENSITY g/ml	%FAT BROZEK	LEAN WT. kg.
1	122	54.0	66.0	1.051	20.51	23.79
2	124	57.0	85.5	1.046	22.43	30.07
3	123	56.0	68.0	1.059	17.23	25.52
4	131	56.5	76.0	1.068	13.31	29.87
5	125	56.0	74.0	1.050	20.80	26.57
6	123	56.0	74.5	1.057	17.96	27.71
7	134	57.0	59.8	1.078	9.41	24.54
8	134	61.0	87.0	1.044	23.17	30.31
9	135	58.5	76.0	1.051	20.38	27.44
10	132	60.0	79.3	1.052	20.00	28.75
11	129	63.0	121.0	1.008	38.77	32.76
12	133	58.5	78.0	1.053	19.73	28.39
13	124	56.0	71.0	1.036	26.54	23.65
14	128	52.0	52.5	1.077	10.15	21.41
15	133	59.0	84.0	1.034	27.41	27.65
16	139	58.0	96.0	1.020	33.83	28.80
17	131	56.0	76.5	1.060	16.53	28.95
18	122	54.5	67.0	1.074	11.15	26.99
19	131	59.0	84.5	1.044	23.15	29.44
20	134	54.0	73.0	1.052	20.05	26.46
21	134	57.0	89.0	1.044	23.23	30.98
22	133	59.0	89.5	1.043	23.85	30.90
23	131	55.0	86.0	1.020	33.62	25.88
24	130	56.5	91.0	1.030	29.10	29.25
25	132	57.0	87.0	1.044	23.34	30.24
26	125	55.0	73.0	1.062	15.85	27.85
27	128	61.0	80.0	1.054	19.01	29.38
28	126	54.0	62.0	1.053	19.66	22.58
29	124	58.5	99.0	1.024	31.97	33.00
30	124	55.5	71.3	1.054	24.19	24.49
31	122	54.0	69.0	1.044	19.38	25.22
32	124	57.0	72.0	1.056	23.44	24.99
33	122	60.0	72.5	1.065	18.28	26.86
34	126	51.0	58.5	1.065	14.68	22.63
35	132	58.0	83.0	1.056	18.31	30.74

TABLE IV (Continued)

SUBJECT	AGE IN MONTHS	HEIGHT IN INS.	WEIGHT IN LBS.	DENSITY g/ml	%FAT BROZEK	LEAN WT. kg.
36	125	55.5	67.0	1.057	18.13	24.96
37	122	56.0	60.5	1.084	7.19	25.46
38	133	53.0	66.5	1.074	11.01	26.83
39	132	54.5	64.0	1.066	14.43	24.83
40	132	59.5	81.5	1.050	20.66	29.32
41	122	52.0	54.0	1.055	18.94	19.85
42	134	54.0	64.0	1.064	15.10	24.64
43	124	52.0	82.0	1.025	31.37	25.52
44	128	57.0	72.0	1.070	12.77	28.48
45	130	56.0	74.0	1.074	11.24	29.78
46	130	49.0	48.5	1.062	15.77	18.52
47	128	61.0	75.0	1.069	13.04	29.57
48	132	54.0	61.0	1.076	10.37	24.79
49	125	60.0	77.0	1.076	10.47	31.26
50	132	54.0	60.5	1.063	15.66	23.13
51	132	51.0	65.0	1.052	20.06	23.56

TABLE V

SKINFOLD MEASUREMENTS OF ALL SUBJECTS

SUBJECT	CHEST SF	MIDAX SF	TRICEP SF	SCAPULA SF	ABDOM. SF	SUP*ILIAC SF	THIGH SF
1	15.0	7.0	12.0	7.0	16.5	14.0	21.0
2	18.0	11.0	19.0	12.0	24.0	22.0	30.0
3	9.0	6.0	14.0	6.0	10.0	10.5	23.0
4	10.0	5.0	11.0	6.0	11.5	11.0	20.0
5	13.0	7.0	17.0	9.0	14.0	19.0	27.0
6	9.5	8.5	16.5	7.5	18.0	17.0	20.0
7	9.0	7.0	12.0	8.0	9.0	9.0	15.0
8	8.0	8.0	17.0	8.5	20.0	20.0	20.0
9	14.0	9.0	12.0	9.0	13.0	12.5	20.0
10	11.0	7.0	10.5	7.5	11.5	11.0	15.5
11	23.0	24.0	32.0	24.0	30.0	35.5	37.0
12	13.0	7.0	17.0	8.5	14.0	16.0	27.0
13	17.0	10.0	17.0	8.5	21.0	19.5	21.5
14	7.0	5.0	11.0	6.0	7.0	7.0	12.0
15	11.0	7.0	11.0	9.0	20.0	15.0	21.0
16	22.0	18.0	21.0	18.0	31.0	32.0	31.0
17	10.0	6.0	11.0	8.5	16.5	13.5	18.0
18	7.0	6.0	9.5	6.0	12.5	9.5	17.0
19	11.0	7.0	14.0	7.0	14.0	13.0	19.0
20	13.0	11.0	14.0	12.0	26.0	22.0	21.0

TABLE V (Continued)

SUBJECT	CHEST SF	MIDAX SF	TRICEP SF	SCAPULA SF	ABDOM. SF	SUP*ILIAC SF	THIGH SF
21	15.0	9.5	18.0	12.0	22.0	19.5	26.0
22	11.5	7.0	17.0	8.5	19.0	14.0	20.0
23	23.5	20.0	23.0	16.5	25.0	22.7	30.0
24	23.0	15.0	27.0	17.0	25.0	30.0	32.0
25	20.0	12.0	23.0	14.0	26.0	27.0	32.0
26	12.0	7.0	12.0	7.0	14.0	13.0	18.0
27	15.0	10.0	18.5	11.0	18.0	15.0	20.0
28	7.0	4.5	10.0	5.0	9.0	8.0	15.0
29	29.0	22.0	26.0	24.0	27.0	32.0	40.0
30	13.0	7.5	15.0	8.5	18.0	21.0	21.5
31	15.0	12.0	20.0	11.0	27.0	18.0	23.0
32	14.0	8.0	12.0	8.0	15.0	12.5	20.0
33	14.5	7.5	12.5	7.5	16.0	11.5	18.5
34	5.0	4.0	8.0	5.0	10.0	8.0	12.0
35	14.0	6.5	14.0	7.0	16.5	15.0	14.5
36	8.0	5.0	11.0	9.0	11.0	8.0	16.0
37	6.0	4.0	8.0	14.0	7.0	5.0	10.0
38	10.0	6.0	11.5	6.0	10.5	10.0	19.5
39	10.0	6.5	13.0	7.0	9.0	9.5	20.0
40	17.0	9.0	15.0	15.0	20.0	20.0	26.5
41	8.0	6.0	11.0	6.5	10.0	.9.0	16.0
42	9.5	6.0	17.0	6.0	11.0	10.0	21.0
43	26.0	18.0	27.0	15.0	31.0	29.0	38.0
44	9.5	6.0	12.5	6.0	12.5	7.5	19.5
45	8.5	6.0	12.0	6.5	11.0	10.0	19.0
46	6.5	6.0	10.5	7.0	7.5	9.5	14.5
47	8.0	4.0	16.0	5.5	7.0	6.0	20.0
48	5.5	5.0	9.0	5.5	7.0	6.0	13.0
49	6.0	4.0	8.5	5.0	6.0	5.0	12.5
50	9.0	5.0	14.5	5.5	10.0	11.0	17.5
51	15.0	7.0	19.0	6.5	12.0	14.0	16.0

TABLE VI

GIRTH MEASUREMENTS OF ALL SUBJECTS

SUBJECT	SHOULD. GIRTH	CHEST G	ABDOM. G	WAIST G	GLUTEAL G	THIGH G	ANKLE G	ARM G
1	80.0	63.0	60.0	55.0	66.0	40.0	18.0	19.0
2	85.0	63.0	63.0	58.0	76.0	42.0	18.5	18.5
3	78.0	63.0	56.0	51.0	67.0	39.0	20.0	19.0
4	84.0	64.0	62.0	55.0	71.0	39.0	18.0	20.0
5	78.0	58.0	57.0	53.0	71.0	40.0	19.0	19.0
6	81.0	59.0	60.0	57.0	71.0	41.0	18.5	20.0

TABLE VI (Continued)

SUBJECT	SHOULD. GIRTH	CHEST G	ABDOM. G	WAIST G	GLUTEAL G	THIGH G	ANKLE G	ARM G
7	78.0	66.0	56.5	55.0	66.0	39.0	17.0	19.0
8	88.0	64.0	62.0	59.0	77.0	42.0	19.0	21.0
9	75.5	63.0	62.0	55.0	72.0	40.0	17.5	20.0
10	81.0	58.0	54.5	54.0	71.0	41.0	19.0	18.0
11	91.0	74.0	67.0	67.0	89.0	50.0	21.5	26.0
12	82.0	63.0	64.0	54.0	71.0	40.0	18.0	20.0
13	80.0	60.0	63.0	56.0	68.0	39.0	19.0	18.0
14	76.0	60.0	52.0	56.0	64.0	36.0	16.5	18.5
15	85.0	65.0	68.0	58.0	75.0	43.0	19.0	20.0
16	89.0	68.0	82.0	66.0	83.0	43.0	19.0	21.0
17	80.0	60.0	55.5	55.0	72.0	42.0	20.0	19.0
18	76.0	59.0	58.0	54.0	67.0	37.0	19.0	18.0
19	81.0	61.0	62.0	57.0	73.0	34.0	18.5	20.0
20	81.0	60.0	66.0	60.0	72.0	40.0	17.0	19.0
21	87.0	67.5	60.0	61.0	76.0	43.5	19.0	21.0
22	88.0	67.0	71.0	59.0	75.0	45.0	20.0	23.0
23	78.0	70.0	66.0	68.0	77.5	41.0	18.0	22.0
24	82.0	66.6	71.0	63.0	80.0	48.0	19.0	23.5
25	87.0	64.0	71.0	61.0	77.0	47.0	20.0	21.0
26	79.0	62.0	57.0	53.0	71.0	39.0	19.0	18.5
27	86.0	63.0	63.0	58.0	77.0	44.0	20.0	22.0
28	72.0	56.0	58.0	53.0	67.0	36.0	18.5	17.0
29	89.0	76.0	78.0	68.0	84.0	50.0	20.0	22.0
30	77.0	57.0	62.0	55.0	70.0	40.0	17.0	18.5
31	79.0	62.0	62.0	58.0	70.0	40.0	17.0	21.0
32	79.0	63.0	64.0	57.0	71.0	40.0	18.0	19.0
33	82.0	59.0	64.0	54.0	70.0	38.0	17.5	19.0
34	76.0	59.0	57.5	52.5	63.0	35.0	17.0	17.0
35	86.0	69.0	65.0	62.0	73.5	42.0	19.0	19.0
36	77.5	61.0	54.0	53.0	67.0	39.0	17.0	18.5
37	78.0	60.0	57.0	48.0	63.0	35.0	17.0	16.0
38	78.0	59.0	57.0	54.0	69.0	41.0	17.0	19.0
39	80.0	59.0	57.0	52.0	66.0	39.0	17.0	20.0
40	87.0	63.0	63.0	56.0	74.0	42.0	18.0	21.0
41	70.0	57.0	57.0	50.0	60.0	34.0	15.0	16.0
42	75.0	56.0	54.0	50.0	63.0	38.0	18.0	18.0
43	89.0	61.0	66.0	60.0	79.0	45.0	19.0	22.0
44	84.0	60.0	54.0	54.5	69.0	39.0	18.0	19.0
45	81.0	71.0	59.0	55.0	68.0	40.0	17.0	18.0
46	71.0	53.0	49.0	49.0	59.0	32.0	15.5	16.0
47	84.0	63.0	54.0	57.0	75.0	41.0	21.0	20.0
48	76.0	57.0	55.0	52.0	64.5	35.0	17.0	18.0
49	82.0	64.5	53.5	55.0	69.0	41.0	18.0	19.0
50	71.0	56.5	51.5	51.0	65.0	37.0	16.5	16.5
51	79.0	61.0	58.0	50.0	67.0	39.0	18.5	18.5

TABLE VII

FOREARM & WRIST GIRTH & DIAMETER MEASURES

SUBJECT	F-ARM G	WRIST C	SHOULD. DIAMETER	BIACRO. D	CHEST D	BITROC. D	BILIAC D	KNEE D	WRIST D
1	19.0	13.0	30.0	22.0	20.0	22.5	20.0	8.0	4.0
2	19.0	13.5	35.0	25.0	23.0	25.0	20.0	9.0	4.5
3	18.0	14.0	32.0	23.0	20.0	23.0	20.0	9.0	4.5
4	19.0	13.5	33.0	26.0	22.0	24.0	19.5	8.5	5.0
5	17.0	12.5	30.0	23.5	20.0	24.0	19.0	9.0	4.5
6	19.0	13.0	30.5	23.0	21.0	24.5	22.0	9.0	4.5
7	19.0	13.0	31.0	24.5	20.0	22.0	17.0	8.0	4.5
8	20.0	14.0	34.5	25.5	22.5	27.5	23.0	9.5	5.0
9	19.0	14.0	31.0	23.0	21.0	24.0	21.5	8.0	4.5
10	18.0	13.0	32.5	25.0	20.0	25.0	19.5	8.5	5.0
11	22.5	16.0	37.0	27.0	24.0	29.0	22.5	9.5	5.0
12	19.0	13.0	33.0	25.0	22.5	24.0	20.0	8.5	5.0
13	18.0	15.0	32.0	25.0	20.0	23.0	19.0	8.5	4.0
14	18.0	12.5	30.0	23.0	21.0	22.0	18.0	8.0	4.5
15	20.0	13.5	33.0	24.0	22.0	25.0	21.0	8.5	4.5
16	20.0	14.0	34.0	26.0	23.0	27.0	23.0	9.5	5.5
17	18.0	13.0	30.5	24.5	20.5	24.0	20.5	9.0	4.5
18	18.0	13.0	30.0	22.0	21.0	22.5	19.0	9.0	5.0
19	20.0	14.0	33.5	24.5	21.5	25.0	20.0	9.0	4.5
20	19.0	13.0	30.0	23.0	20.0	24.0	19.5	9.0	4.5
21	20.0	13.5	35.0	25.0	22.0	25.5	22.0	9.0	4.5
22	19.5	14.0	34.0	26.0	23.0	25.5	22.5	9.5	4.5
23	20.0	13.5	30.5	21.5	22.0	24.0	21.5	8.5	4.4
24	22.0	15.0	33.0	24.0	23.5	25.5	21.5	9.0	4.5
25	20.0	13.0	34.5	25.0	23.0	26.0	22.5	9.5	4.5
26	19.5	13.0	31.0	23.0	20.0	23.0	19.5	8.5	4.5
27	21.0	15.0	32.0	24.5	21.0	23.5	20.0	9.0	5.0
28	17.0	13.0	29.0	23.0	20.0	23.5	18.5	8.0	4.0
29	21.0	14.0	35.0	24.0	24.0	27.5	24.5	9.9	5.0
30	18.0	13.5	30.0	23.0	21.0	23.0	18.5	8.5	4.5
31	19.0	12.0	31.0	24.5	24.5	24.0	20.0	8.0	4.0
32	18.5	13.5	31.0	20.5	21.0	23.5	21.0	8.5	4.0
33	18.5	13.0	32.0	26.0	21.5	24.5	20.0	9.0	5.0
34	17.0	12.5	30.0	22.0	20.0	22.0	18.0	8.0	4.5
35	19.0	14.0	35.0	25.5	24.0	26.5	21.0	8.5	4.5
36	18.0	13.0	30.5	24.5	21.5	23.0	20.0	8.0	4.5
37	17.0	13.0	32.0	24.0	21.0	22.0	18.0	8.0	4.5
38	18.5	12.5	29.0	21.5	19.5	23.5	20.0	8.5	4.5
39	18.0	12.5	31.0	26.0	20.0	22.5	20.0	8.0	4.0
40	19.0	14.5	33.0	25.0	22.0	24.0	22.0	8.5	4.0
41	17.0	11.5	28.0	21.5	19.5	21.0	17.0	8.0	4.0
42	18.0	13.0	31.0	24.0	21.0	22.5	20.0	8.0	4.5
43	20.0	13.5	35.0	27.0	23.0	25.0	21.0	9.0	4.5
44	18.0	13.0	32.0	27.5	21.0	25.5	20.0	8.5	4.5
45	18.5	12.0	33.0	25.0	24.0	24.0	21.0	8.5	4.0

TABLE VII (Continued)

SUBJECT	F-ARM G	WRIST G	SHOULD. DIAMETER	BIACRO. D	CHEST D	BITROC. D	B-ILIAC D	KNEE D	WRIST D
46	15.0	11.0	27.0	22.0	19.0	20.0	16.5	8.0	4.0
47	19.0	15.0	34.0	27.0	21.0	26.0	20.0	9.5	5.0
48	18.0	13.0	29.0	23.5	19.5	22.5	19.0	8.0	4.5
49	19.5	13.5	33.0	26.5	21.0	24.0	19.5	9.0	5.0
50	18.0	12.0	30.0	23.0	19.5	22.0	19.0	8.0	4.0
51	19.0	13.0	31.0	25.0	20.0	22.0	19.0	7.5	4.0

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