South Dakota State University

Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Electronic Theses and Dissertations

1959

Changes in Body Fat as Computed from the Skinfold Measurement of College Track and Field Athletes During a Season of Competition and Training

Richard Arnold Walker

Follow this and additional works at: https://openprairie.sdstate.edu/etd

Recommended Citation

Walker, Richard Arnold, "Changes in Body Fat as Computed from the Skinfold Measurement of College Track and Field Athletes During a Season of Competition and Training" (1959). *Electronic Theses and Dissertations*. 2620.
https://openprairie.sdstate.edu/etd/2620

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.

CHANGES IN BODY FAT AS COMPUTED FROM THE SKINFOLD MEASUREMENT OF COLLEGE TRACK AND FIELD ATHLETES DURING A SEASON OF COMPETITION AND TRAINING

BY

RICHARD ARNOLD WALKER

A thesis submitted
in partial fulfillment of the requirements for
the degree Master of Science, Department of
Physical Education, South Dakota
State College of Agriculture
and Mechanic Arts

August, 1959

SOUTH DAKOTA STATE COLLEGE LIBRARY

CHANGES IN BODY FAT AS COMPUTED FROM THE SKINFOLD MEASUREMENT

OF COLLEGE TRACK AND FIELD ATHLETES DURING A SEASON

OF COMPETITION AND TRAINING

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation for the help and guidance given by his adviser, Professor Glenn E. Robinson. Gratitude is also expressed to Coach Jim Emmerich and the 1959 South Dakota State College Varsity Track and Field Team for their co-operation in this study.

R.A.W.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The distinguished British physiologist, A. V. Hill, in speaking of the relationship of physiology to athletics said:

> The practice of athletics is both a science and an art, just as art and science are the most potent ties tending to draw men together in a world of industrial competition, so sport and athletics, by urging men to friendly rivalry, may help avert the bitterness resulting from less peaceful struggles. If, therefore, physiology can aid in the development of athletics as a science and an art, I think it will deserve well of mankind.[1]

The effects of training on the body, in relation to the heart, blood, respiration, and the muscular system, have been thoroughly examined by physiologists. The results of athletic competition on the body fat of man has not recieved such close scrutiny.

Statement of the Problem

The purpose of this study was to determine the changes in body fat as computed from the skinfold measurement of college track and field athletes of South Dakota State College during a season of competition and training. The effect of track conditioning on gain or loss of weight was also examined.

---

[1]Graham Lusk, "The Influence of Mechanical Work on Metabolism", The Elements of the Science of Nutrition, 4th Ed., p. 446, W. B. Saunders Company: Philadelphia, Pa., 1928.

Delimitations of the Problem

This study was limited to testing varsity track and field athletes of South Dakota State College whose training and competition commenced in January, 1959 and ended in June, 1959. It is also probable that the results of this study were modified by the fact that some of the subjects had been members of the cross country team and as such were partially trained at the beginning of this study.

Significance of the Problem

Body fat has been the subject of numerous studies in health, nutrition, physical fitness, and somatotyping. The relationship of body fat to athletic training and performance has not received as much attention from physical educators. It was anticipated that this study would reveal significant information for the profession concerning athletic training and the gain or loss of subcutaneous fat.

Fat and Adiposity

Fat is a compound composed of three molecules of fatty acid and one of glycerin.[2] Fat tissue is composed of specialized cells which have the ability to take up fat and store it, a

---

[2]E. Cheraskin and L. L. Langley, "Absorption and Utilization", The Physiology of Man, p. 425, McGraw-Hill Book Company, Inc.: New York, 1954.

single globule within the interior of each cell. Numbers of fat cells are held together in mass by connective tissue.[3] Body fat accounts for about 18 percent of the total body weight of men and about 28 percent of the body weight of women.[4] Fat functions as insulation for mammals. It is a poor conductor of heat and thus is very effective in conserving body temperature. Women generally resist the cold better then men because they are equipped with more insulating fat.[5] Fat deposits serve to protect the internal organs. The kidneys, for example, are largely held in place by fat.[6] Gemmill demonstrated that fats can be used indirectly for muscular work. This process is an effective method, as muscular efficiency is not effected for short periods of exercise.[7] When carbohydrates are depleted, fats serve as the primary source of energy; the amount being used sometimes increasing to three-fourths

---

[3]Anton J. Carlson and Victor Johnson, "The Unit of Structure and Function--The Cell", The Machinery of the Body, p. 16, The University of Chicago Press: Chicago, Illinois, 1948.

[4]L. E. Morehouse and P. J. Rasch, "Kinesiological Factors in Athletics", Scientific Basis of Athletic Training, p. 22, W. B. Saunders Company: Philadelphia, Pa., 1958.

[5]Carlson and Johnson, op. cit., p. 33.

[6]L. Jean Bogert, "Fatty Foods", Nutrition and Physical Fitness, 5th Ed., p. 29, W. B. Saunders Company: Philadelphia, Pa., 1949.

[7]Chalmers L. Gemmill, "The Fuel for Muscular Exercise", Physiological Reviews, vol. 22, 49, American Physiological Society: Baltimore, Maryland, January, 1942.

of the fuel used.[8] Morehouse and Miller suggested that athletes in training should not have more than 25 percent of their daily calories supplied by fat because it is not directly used as fuel for muscular exercise.[9]

Adiposity refers to the fat stored in the cells of loose connective tissue distributed throughout the body. These collections of fat are utilized mainly for storage purposes and can be called upon by the body when required. The various fat depots are located in the subcutaneous tissue, genital, perenal, mesenteric, intermuscular, and omental regions. Approximately 50 percent of all the fat in the body is located in the subcutaneous tissue.[10] The word "adiposity" refers mainly to the subcutaneous tissue and was used as such in this study.

---

[8] Sarah R. Riedman, "Chemical Dynamics in Muscular Work", _The Physiology of Work and Play_, p. 87, The Dryden Press: New York, 1952.

[9] L. E. Morehouse and A. T. Miller, "Diet", _Physiology of Exercise_, p. 291, C. V. Mosby Company: St. Louis, Missouri, 1948.

[10] L. B. Mendel, "Some Relations of Diet to Fat Depositions in the Body", _Yale Journal of Biology and Medicine_, vol. 3, 107-137, New Haven, Connecticut, October, July, 1930-31.

CHAPTER II

REVIEW OF RELATED LITERATURE

A published study by Thompson, Buskirk, and Goldman of Boston University has direct application to the problem. Testing 14 basketball players and 12 hockey players, before and after the season, revealed a significant loss of fat at the three sites measured. Body weight remained relatively constant, with the basketball players losing a mean of 0.94 kg. and the hockey athletes losing an even smaller amount of weight, an average of 0.42 kg. of body weight.[11] Further study was made by Thompson on 34 members of the Boston University varsity football team. Skinfold measurements and weight were taken at the beginning and end of the football season, a period of about 12 weeks. The mean weight loss, 1.49 kg., was not significant. However, the skinfold measurements at three sites showed decreases which were all significant. Abdominal tissue decreased 5.76 mm., chest tissue decreased 4.94 mm., and upper arm tissue decreased 1.44 mm. These three decreases were significant at the one percent level.[12]

---

[11] C. W. Thompson, E. R. Buskirk, and R. F. Goldman, "Changes in Body Fat, Estimated from Skinfold Measurements of College Basketball and Hockey Players During a Season", The Research Quarterly, vol. 27, 418-420, American Association for Health, Physical Education, and Recreation: Washington, D.C., December, 1956.

[12] C. W. Thompson, "Changes in Body Fat, Estimated from

Significant skinfold measurement differences and little loss of body weight suggested a change in body density and the possibility that body fat had changed to muscle tissue as a result of the strenuous athletic activity.

Welham and Behnke demonstrated that weight is not necessarily a valid indication of excessive fatness. In their study of professional football players they concluded that the athletes were low in fat content, although their mean body weight was 24.6 percent above the Naval standards for men of the same height and weight.[13]

In a very comprehensive analysis of body composition of 12 soldiers, in paratrooper training, Pascale, et al, found a mean body weight loss of 0.6 kg. These men, engaged in an intensive three week course, had the thickness of their skinfolds decrease significantly at most of the sites measured.[14] It was interesting to note that the body fat changes came in a relatively short training time, and that the men initially

---

Skinfold Measurements of Varsity College Football Players during a Season", The Research Quarterly, vol. 30, 87-90, American Association for Health, Physical Education, and Recreation: Washington, D. C., March, 1959.

[13]W. C. Welham and A. R. Behnke, "Specific Gravity of Healthy Men. Body Weight Volume and Other Physical Characteristics of Exceptional Athletes and of Naval Personnel", Journal of the American Medical Association, vol. 118, 498, American Medical Association: Chicago, Illinois, February 14, 1942.

[14]L. R. Pascale, et al, "Report of Changes in Body Composition of Soldiers During Paratrooper Training", 9937 TU Medical Nutrition Laboratory Report No. 156, United States Army, Fitzsimons Army Hospital: Denver, Colorado, March 22, 1955.

were in a good state of physical fitness, having just completed a 16 weeks basic training course.

Tanner made detailed anthropometric measurements on ten healthy young men of predominantly mesomorphic physique, who were under the guidance of a weight-training instructor for a period of four months. The most notable change was an increase in the circumference of the upper arm which was not accompanied by concurrent changes in thickness of subcutaneous tissue, and could be attributed to an increase in muscular tissue.[15]

In another example of body change in training, Seltzer measured the chest circumference in mid-inspiration of 272 American Air Force cadets before and after an eight weeks course of severe physical training. One of the conclusions of the general effect of training was to increase the circumference of the chest.[16]

In an experiment, using animals, Morse and Schlutz exercised ten short-haired male dogs, weighing 9 to 14 kgs., on a motor-driven treadmill and swimming in a tank of water. In the treadmill experiment the dogs were weighed before exercise and after termination of the exercise. Conclusions show that

---

[15] J. M. Tanner, "The Effect of Weight-Training on Physique", <u>American Journal of Physical Anthropology</u>, vol. 10, 458-459, The Wistar Institute of Anatomy and Biology: Philadelphia, Pa. December, 1952.

[16] C. C. Seltzer, "Chest Circumference Changes as a Result of Severe Physical Training", <u>American Journal of Physical Anthropology</u>, vol. 4, 389-393, The Wistar Institute of Anatomy and Biology: Philadelphia, Pa., September, 1946.

the loss of body weight occurred during treadmill exercise and that the loss of weight per kilo of body weight was roughly related to the duration of the exercise period. Losses of body weight, to the time of exhaustion in minutes, ranged from 17 gm. per kgm. and 40 minutes, to 85 gm. per kgm. and 450 minutes.[17]

Grover made an important contribution in his analysis of Springfield College students. They were subjected to strenuous treadmill running for 30 minutes, three times per week, over 30 minute periods. This training caused an appreciable loss of fat.[18]

Dr. Thomas K. Cureton and his associates, at the University of Illinois, accomplished a great deal of research in the area of physical fitness and in isolating factors which were responsible for reduction of body fat. Cureton made six measurements on the 1948 United States Olympic swimming team and in comparison with the 1936 Olympic swimming team, found the 1948 team to have about 2 mm. less external fat per measurement. He stated, "This indicates that the 1948 team as a group had

---

[17]Minerva Morse and Frederic W. Schlutz, "Factors Influencing the Concentrations of the Serum Protein, Chloride and Total Fixed Base of the Dog During Exercise", The American Journal of Physiology, vol. 121, 296, American Physiological Society: Baltimore, Maryland, 1938.

[18]G. H. Grover, An Approximate Analysis of Adipose Tissue in Relationship to Nutrition, Condition, and Skeletal Size, p. 87, Unpublished Master's Thesis, Springfield College: Springfield, Massachusetts, 1936.

less predispostion to endomorphy, or that as a group they approached more closely optimum physical condition, since strenuous physical conditioning tends to reduce external fat pads."[19]

In a dissertation concerned primarily with the exclusion of endurance type activities and the substitution of too many motor skills in the daily physical education program, Cureton indicated that he thought the age of the individual would have a bearing on weight gained or lost. Younger athletes, in a relatively good state of training would not lose weight and some may even gain additional weight. Older people need one or two months before they will be able to show an appreciable loss of adipose tissue. Furthermore, although body fat is reduced, the individual may appear to make no real gain, as endurance exercises will increase muscle density and bulk.[20]

Continuing his theory that the modern day physical education program lacks enough endurance activities, Cureton found that exercise must be long enough to reduce weight and fat. He recommended 30 minutes or more of hard exercise in such pursuits as swimming, hard rhythmic calisthenic training, and

---

[19] Thomas K. Cureton, "Analysis of the Weight of Champions", <u>Physical Fitness of Champion Athletes</u>, p. 53 University of Illinois Press: Urbana, Illinois, 1951.

[20] Thomas K. Cureton, "The Effect of Physical Training, Sports, and Exercises on Weight, Fat, and Tissue Proportions", <u>American Academy of Physical Education</u>, Professional Contributions No. 6, pp. 31-37, American Association for Health, Physical Education, and Recreation: Washington, D. C., November, 1959.

51

long distance swimming or cycling.[21]

In a thorough investigation, aimed at determining the effects of mild, moderate, and vigorous physical activity on adipose tissue, Kireilis established three classifications. Eighteen students were measured in six places with fat calipers every two weeks for a period of six weeks. The Basic Fitness Class, a vigorous physical activity group, participated in long endurance running and lost the most fat, the amount averaging 5.77 mm. The Life Saving Class, the moderate physical activity group, lost an average of 2.5 mm. of adipose tissue per student. In the Adapted Sports Class, a mild physical activity group, exercises consisted of calisthenics and light recreational activity. This group lost the least amount of fat, an average of 1.36 mm. per individual. Although adipose tissue losses for the three groups were significant, weight reductions were not. The Basic Fitness Class lost 1.6 pounds, the Life Saving Class 1.9 pounds, and the Adapted Sports Class lost .8 pounds per student. Kireilis stated, "This shows that the more vigorous physical training programs bring about greater losses of adipose tissue than do the moderate and mild physical activities. Also that the degree of intensity of vigorous,

---

[21]Thomas K. Cureton, "The Value of Hard Endurance Exercises and Tests to Produce Changes in Weight, Fat, Metabolism and Cardivascular Condition", College Physical Education Association, 61st Annual Proceedings, pp. 162-65, American Association for Health, Physical Education, and Recreation: Washington, D. C., 1958.

moderate, and mild physical activities reduces the adipose tissue in proportion to the intensity of the physical activity." Kireilis concluded, "The loss of adipose tissue and the negligible loss of weight suggests that the muscle tone must have increased; therefore, it is assumed that muscular development had occurred to offset any possible loss of weight."[22]

Cureton supervised the rejuvenation of the physical fitness and organic efficiency of a 59 year old man. A six months program, which included walking two miles per day, five days a week, home calisthenics twice a day for 10 to 15 minutes per day, and golf or a long hike once a week, resulted in a reduction of over-all fat by 28 percent standard score.[23]

Kroll examined the anthropometrical characteristics of 35 varsity wrestlers, from four Big Ten schools, when they came to Illinois to compete in dual meets. One of the conclusions was that the fat measurements of the wrestlers were extremely low.[24]

---

[22] R. W. Kireilis, The Relation of Physical Training to Adiposity, pp. 100-102, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1944.

[23] Thomas K. Cureton, Physical Fitness Improvement of a Middle Aged Man, with Brief Reviews of Related Studies", The Research Quarterly, vol. 23, 149-150, American Association for Health, Physical Education, and Recreation: Washington, D. C., May, 1952.

[24] Walter Kroll, "An Anthropometrical Study of Some Big Ten Varsity Wrestlers", The Research Quarterly, vol. 24, 308-309, American Association for Health, Physical Education, and Recreation: Washington, D. C., October, 1954.

Cureton found that the endomorphs gave poor physical performances in comparison with mesomorphs in such activities as the Rogers Strength Index, sprinting, the 440 yard run, the broad jump, and the Cosens test. In checking performances of strenuous physical exercises and external fat on the body, negative correlations ranging from -0.578 to -0.264 were found to exist between these two. The correlations between distance running and external fat were greater (negative) then for any other test administered.[25]

Likewise, Bookwalter, testing boys in grades four to eight, found that shape and size seemed to influence physical performance, as measured by the Indiana Physical Fitness Test. He concluded that the very obese boys were the poorest performers.[26]

Kireilis and Cureton selected three relatively fat students, of the endo-mesomorphic somatotype, from the physical education classes at the University of Illinois. Body weight and six adipose measurements were taken for the entire training period of 30 minutes for six weeks, three times per week. Strenuous treadmill running resulted in an appreciable loss of

---

[25]Thomas K. Cureton, "Body Build as a Framework of Reference for Interpreting Physical Fitness and Athletic Performance", The Research Quarterly, Supplement, vol. 12, 328-330, American Association for Health, Physical Education, and Recreation: Washington, D. C., May, 1941.

[26]K. W. Bookwalter and others, "The Relationship of Body Size and Shape to Physical Performance", The Research Quarterly, vol. 23, 271-279, American Association for Health, Physical Education, and Recreation: Washington, D. C., October, 1952.

external fat. Adipose tissue, on the abdomen and buttocks, was a large handicap with negative correlations in the performances running from -0.737 to -0.588. As a result of this type of exercise, relatively more fat was lost from the hips, rear thigh, and buttocks than from the cheeks, front thigh, and abdomen.[27]

Campney tested one 25 year old male subject for eight weeks in a moderate conditioning program one hour a day, five times a week, with swimming, calisthenics, and squash. A five weeks deconditioning program was included in which the individual did nothing. Adipose tissue was reduced during training and began to accumulate with detraining.[28]

Kristufek, 22 years old, underwent a vigorous training program of five days a week, for seven weeks, and showed significant changes in muscle girth and body fat. His weight loss over this period of time was five pounds. There were losses in all of the fat measurements taken with an average total decrease of 22 mm. in 14 places. The total fat was reduced from 130 mm.

---

[27] R. W. Kireilis and Thomas K. Cureton, "The Relationships of External Fat to Physical Education Activities and Fitness Tests", The Research Quarterly, vol. 18, 123-129, American Association for Health, Physical Education, and Recreation: Washington, D. C., May, 1947.

[28] Harry K. Campney Jr., The Effects of a Combined Program of Physical Activity on the Physical Fitness of an Adult Male, p. 135, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1953.

134321 SOUTH DAKOTA STATE COLLEGE LIBRARY

to 108 mm.[29]

The effects of two varying physical education summer programs on the adiposity of young boys was studied by Mas. Three daily 600 yard runs were used and one stamina test administered each day in swimming, track and field, and gymnastic classes. Prior to 1956, endurance training was not a part of the summer program and upon inclusion of endurance training, positive reductions in adiposity were noted. Endurance training had a tendency to reduce the fat on the parts of the body that were exercised. Reduction was noted at the gluteal, front thigh, and rear thigh points of measurement.[30]

However, a lack of duration and intensity in exercising may produce no appreciable results in the reduction of fat. Hopkins supervised a six months activity program of volleyball and calisthenics for a selected group of men. One of the conclusions found that fat on the body remained practically the same, the training having no effect.[31]

Four middle-aged men, ranging in age from 27 to 39 years, participated as experimental subjects for Herden. This

---

[29] Charles J. Kristufek, *Effect of Endurance Training on an Adult Subject*, pp. 82-84, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1951.

[30] Joseph Mas, *The Effect of Physical Activity on the Adiposity of Young Boys*, pp. 65-67, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1957.

[31] Richard E. Hopkins, *The Effects of Volleyball and Calisthenics on the Physical Fitness of Adult Men*, p. 85, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1951.

program consisted of walking on the Health-Walker up a 14 percent grade, 30 minutes per day, five days a week, for eight consecutive weeks. A daily record was kept of the total yards walked during the 30 minute exercise period and from this the speed of walking was calculated. Adipose tissue did not change during the course of the experiment and the training program had no effect on external fat.[32]

Excessive fat has generally been considered to be undesirable for endurance type athletes. McLester and Darby believed that too much fat interfered materially with physical activity, reduced muscular efficiency, and when found in excessive amounts in the abdominal cavity, interfered with movements of the diaphragm and abdominal muscles.[33] Morehouse and Miller suggested that as little fat as possible was best for the distance runner and high jumper. These athletes must move their weight as economically as possible and added weight reduces strength and endurance.[34] After analyzing weight

---

[32]E. L. Herden, The Effects of the Health-Walker Dynamic Exercise Machine on the Physical Fitness of Two Adult Men, pp. 210-212, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1954.

[33]James S. McLester and William J. Darby, "Obesity and Leanness", Nutrition and Diet in Health and Disease, 6th Ed., p. 334, W. B. Saunders Company: Philadelphia, Pa., 1952.

[34]L. E. Morehouse and A. T. Miller, "Diet", Physiology of Exercise, p. 288, C. V. Mosby Company: St. Louis, Missouri, 1948.

gains of trackmen and other athletes, Montoye, et al, found the trackmen to gain more than other athletes. He suggested that trackmen were lighter in college than other athletes and they were usually trained to a finer edge than other athletes.[35] Cureton also felt that athletes should be lean. He said, "Everyone knows from practical experience that if a man becomes fat he becomes slow, lacks endurance and lags behind in competition."[36]

The foregoing related studies were similar in many ways to the present problem. Exercise of various kinds was shown to produce weight loss in athletes under the proper conditions. Under other circumstances exercise alone seemed to cause no significant loss of body fat. These studies did, however, assist in formulating the procedures and plans for this investigation and in understanding more completely its results.

---

[35] Henry J. Montoye, et al, "Weight Analysis", The Longevity and Morbidity of College Athletes, p. 70, Phi Epsilon Kappa Fraternity: East Lansing, Michigan, 1957.

[36] Thomas K. Cureton, Physical Fitness Workbook, p. 120 Stipes Publishing Company: Champaign, Illinois, 1942.

CHAPTER III

PROCEDURES

Review of Measurement Technique

Several indirect methods for measuring body fat have been described by Brozek and Keys. They included measurement of the thickness of the subcutaneous tissue, estimation of the total body fat from the specific gravity, estimation of the total body water, and the use of roentgenograms or x-rays.[37] The skinfold technique was chosen because of the comparatively smaller expense involved in purchase of the calipers and because of the relatively simple and rapid manner that the inexperienced individual can learn to manipulate the instrument.

Pinching the skinfold with the fingers, as an aid in determining the nutritional status of the child, has been an old medical technique used by physicians. Richer, in 1890, was given credit as one of the first men to use calipers to measure skinfold thickness.[38] Skinfold calipers have improved

---

[37] J. Brozek and A. Keys, "Evaluation of Leanness-Fatness in Man: A Survey of Methods", Nutrition Abstracts and Reviews, vol. 20, 248, Commonwealth Bureau of Animal Nutrition, Rowett Research Institute: Bucksburn, Aberdeenshire, Scotland, October, 1950.

[38] C. W. Thompson, E. R. Buskirk, and R. F. Goldman, "Changes in Body Fat, Estimated from Skinfold Measurements of College Basketball and Hockey Players During a Season", The Research Quarterly, vol. 27, 419, American Association for Health, Physical Education, and Recreation: Washington, D. C., December, 1956.

considerably in both accuracy and reliability in recent times. Franzen, whose calipers were used by McCloy in establishing norms, made a detailed study of 7500 public school children in 1927 and 1928. He found that two of the three measurements of subcutaneous tissue showed objectivities of 0.94.[39]

Garns measured the fat of the lower rib at the mid-axillary line on 65 young men, 21 to 22 years old. His results revealed a reliability of 0.88 between the calipers and the x-ray technique.[40]

Thompson, in his study of football players and the effects of conditioning on body fat, found high correlations between sites as follows: abdomen and chest r=0.88; abdomen and arm r=0.79; and chest and arm r=0.88.[41] Similarly, a study of basketball and hockey athletes disclosed inter-correlations between skinfolds ranging from 0.70 to 0.95.[42]

---

[39]Raymond Franzen, "An Analytic Account of Muscle Size and Amount of Subcutaneous Tissue", Physical Measures of Growth and Nutrition, p. 47, Number II of the School Health Monographs, American Child Health Association, J. J. Little Ives Company: New York, 1929.

[40]S. M. Garns, "Comparison of Pinch Caliper and X-Ray Measurements of Skin Plus Subcutaneous Fat", Science, vol. 124, 178-179, American Association for the Advancement of Science: Washington, D. C., July 27, 1956.

[41]C. W. Thompson, "Changes in Body Fat, Estimated from Skinfold Measurements of Varsity College Football Players during a Season", The Research Quarterly, vol. 30, 90, American Association for Health, Physical Education, and Recreation: Washington, D. C., March, 1959.

[42]Thompson, Buskirk, and Goldman, op. cit., p. 420.

A comprehensive study by Grover on 18 students, using six measurements per student on the cheeks, abdomen, hips, gluteals, rear thigh and front thigh, showed reliabilities of 0.90. All measurements were made three times to insure accuracy.[43]

Josef Brozek and Ancel Keys, nutritionists of international note, have accomplished a large amount of research on the body fat content of man. In writing of the accuracy of skinfold measurements, they stated:

> The validity of the skinfold values as measures of subcutaneous fat seems to be satisfactory. There is general agreement that the thickness of the skin proper varies little and that the differences in the thickness of skinfolds are referable to the differing thickness of the subcutaneous layer.[44]

> The thickness of the subcutaneous fat may be determined with ease by skinfold calipers in a large number of sites. Under conditions of normal hydration, the principal source of error of measurement of subcutaneous fat, outside of positioning and lifting of the skin, is variation in the thickness of the skin proper.[45]

In one survey, measuring a representative sample of 133 college men, mean age--20.3 years, Brozek and Keys found correlations ranging from 0.752 to 0.938 for the five points

---

[43]G. H. Grover, An Approximate Analysis of Adipose Tissue in Relationship to Nutrition, Condition and Skeletal Size, pp. 33-39, Unpublished Master's Thesis, Springfield College: Springfield, Massachusetts, 1936.

[44]Brozek and Keys, op. cit., p. 254.

[45]A. Keys and J. Brozek, "Body Fat in Adult Men", Physiological Reviews, vol. 33, 249, The American Physiological Society: Washington, D. C., July, 1953.

measured; the abdomen, chest, back, arm, and thigh.[46] Furthermore, the coefficient of multiple correlation between specific gravity and skinfolds was 0.871 measured at three points of the body surface.[47]

Sites of Measurement

There appears to be general uniformity among experts as to the sites on the body to be selected for measurement. The Interdepartmental Committee on Nutrition for National Defense listed the following:

> Arm—Taken at the midposterior midpoint between the tip of the acromion and the tip of the olecranon with the elbow in 90 degree flexion.
>
> Chest:
> (1) At the level of the xiphoid in the midaxillary line.
> (2) Midpoint between anterior crease of the axilla and the nipple.
> (3) Just adjacent to the nipple along the line of No. 2 but not including any glandular tissue.
>
> Abdomen—Waist Level:
> (1) At the midaxillary line.
> (2) On the extension of the midclavicular line.[48]

Thompson used these three sites in both of his studies showing the change of body fat estimated from skinfold

---

[46]Brozek and Keys, op. cit., p. 205

[47]J. Brozek and A. Keys, "Body Build and Body Composition", Science, vol. 116, 141-142, American Association for the Advancement of Science: Washington, D. C., August 8, 1952.

[48]Interdepartmental Committee on Nutrition for National Defense, "Clinical Appraisal of Nutriture", Manual for Nutrition Surveys, p. 30, U. S. Government Printing Office: Washington, D. C., May, 1947.

measurements:

(a) Chest--About 5 cm. from the right nipple on a line toward the uppermost point of the axillary fold (skinfold parallel to this line).

(b) Upper arm--Over the right triceps, halfway between the olecranon and acromial processes (skinfold parallel to the long axis of the arm).

(c) Abdomen--Approximately 5 cm. to the right of the umbilicus (skinfold oriented laterally).[49]

Kireilis patterened his choice of measurement sites after those selected by Grover which were:

Cheeks. Measurement was made on the right cheek, level with the lower part of the nose, at the center of the cheek.

Abdomen. The measurement was made two inches to the left of the navel.

Hips. Measurement was made on the right hip at a point located at the center of the saffital plane of the body, and the top of the crest of the ileum or hip bone.

Gluteal. Measurement was made on the left buttocks, level and a little to the left of the gluteal fold.

Rear Thigh. Measurement was made at the center of the rear thigh halfway between the knee and cleft of the gluteal fold with the foot relaxed and off the ground.

Front Thigh. Measurement was made at the center of the front thigh halfway between the knee and the groin with the foot relaxed and off the ground.[50]

Three of the four sites chosen for this study were identical with those used by Thompson, while one (the cheek) was described by Grover. The sites selected for this

---

[49] Thompson, op. cit., p. 88.

[50] Grover, loc. cit.

investigation were:

A. Chest—About 5cm. from the right nipple on a line toward the uppermost point of the axillary fold (skinfold parallel to this line).

B. Cheek—Measurement was made on the right cheek, level with the lower part of the nose, at the center of the cheek.

C. Abdomen—Approximately 5 cm. to the right of the umbilicus (skinfold oriented laterally).

D. Upper Arm—Over the right triceps, halfway between the olecranon and acromial processes (skinfold parallel to the long axis of the arm).

Use of Calipers

The calipers selected for this study, manufactured by the MNL-Medical Nutrition Laboratory, Denver, Colorado, exerted a pressure of at least 10 gm./mm.^{2}, as the measured skinfold thickness was highly dependent on caliper pressure until at least 10 gm./mm.^{2} was reached. In making the measurements the skinfold was lifted by the thumb and index finger and held about 1-1.5 cm. away from the fingers. Standard pressure was exceeded at first to reduce early changes resulting from body fluid shifts. The span of the grasp was dependent on the thickness of the skinfold. The size of the fold should be enough to include two thicknesses of skin and subcutaneous

fat, but not muscle or fascia.[51]

Test Administration

Each skinfold was measured three times. The reported results were recorded in centimeters and were the mean of the three measurements. These constituted the raw scores for this study.

Body weight was recorded in pounds on a U. S. Physican's diagnostic scale, manufactured by Jacobs Brothers Company, New York, New York.

The size of the original sample of 38 men tested was reduced to 23 track and field athletes at the end of the testing period because of withdrawal from the sport or school, injuries, ineligibilities, and other attritional factors. The athletes were tested five times, the first examination on January 15, 1959 and the fifth on May 15, 1959. Tests were administered on the fifteenth day of every month or approximately every 30 days of training.

Training Conditions

Because of a lack of an indoor running track of any nature, the athletes' conditioning during the winter months was limited largely to vigorous activities inside the gymnasium

---

[51]Keys and Brozek, op. cit., pp. 245-249.

and to running outdoors when the weather permitted. However, indoor competition was engaged in with the first meet held January 31, 1959. From approximately April 1, 1959, to the end of the season, June 13, 1959, the athletes trained outdoors.

Figure 1. Calipers Used: MNL-Medical Skinfold Calipers

Figure 2. Site A: Measuring Skinfold of the Chest

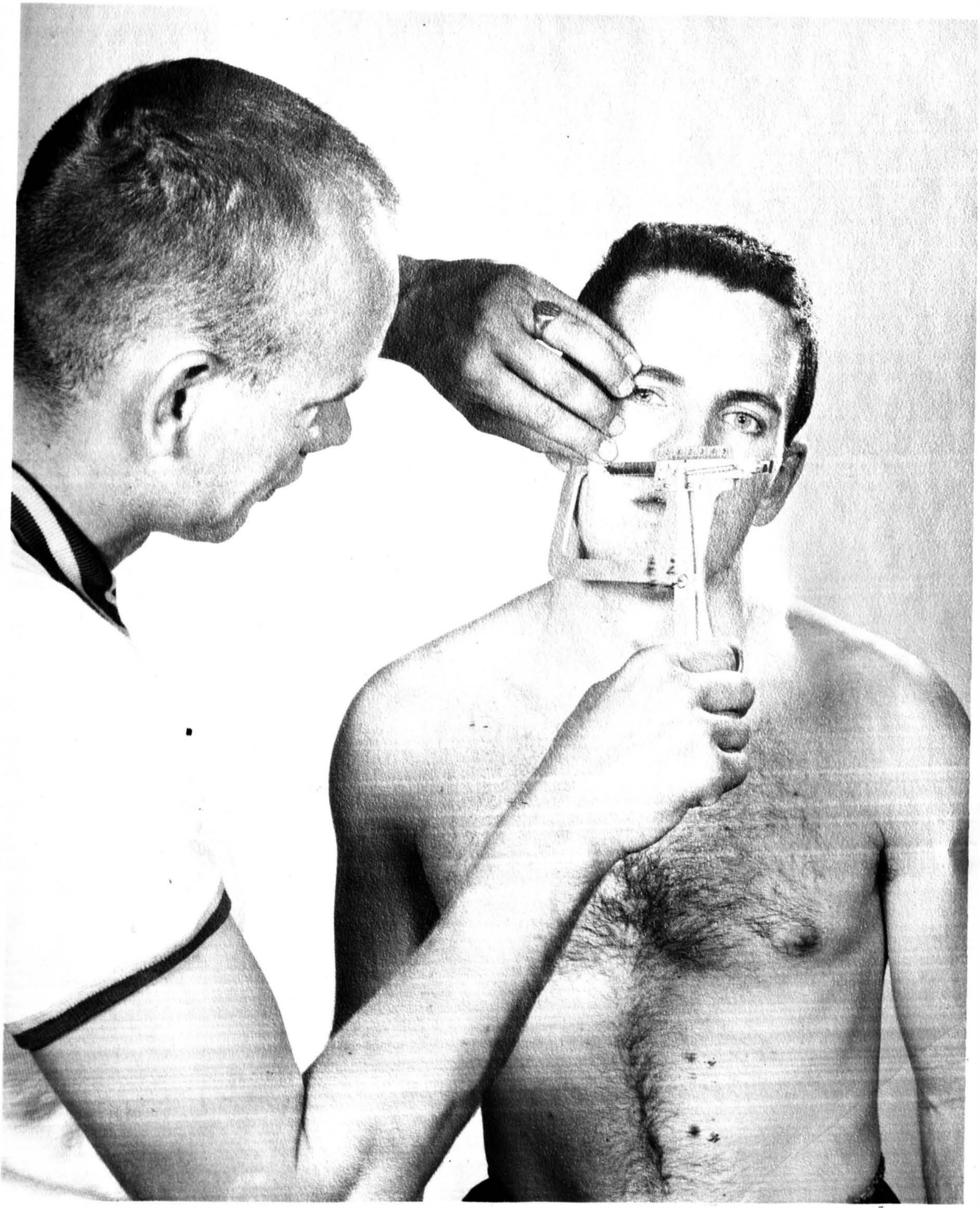

Figure 3. Site B: Measuring Skinfold of the Cheek

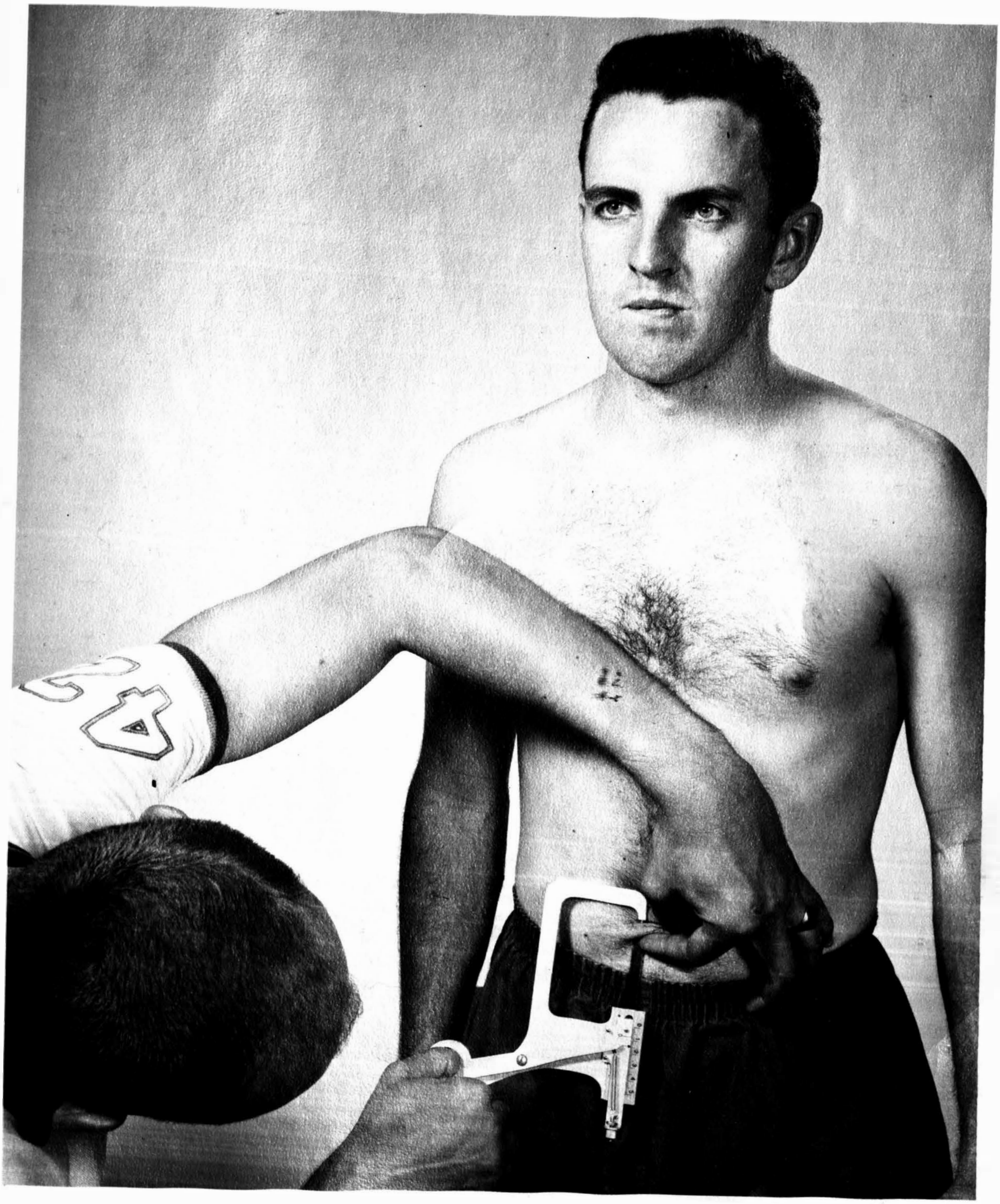

Figure 4. Site C: Measuring Skinfold of the Abdomen

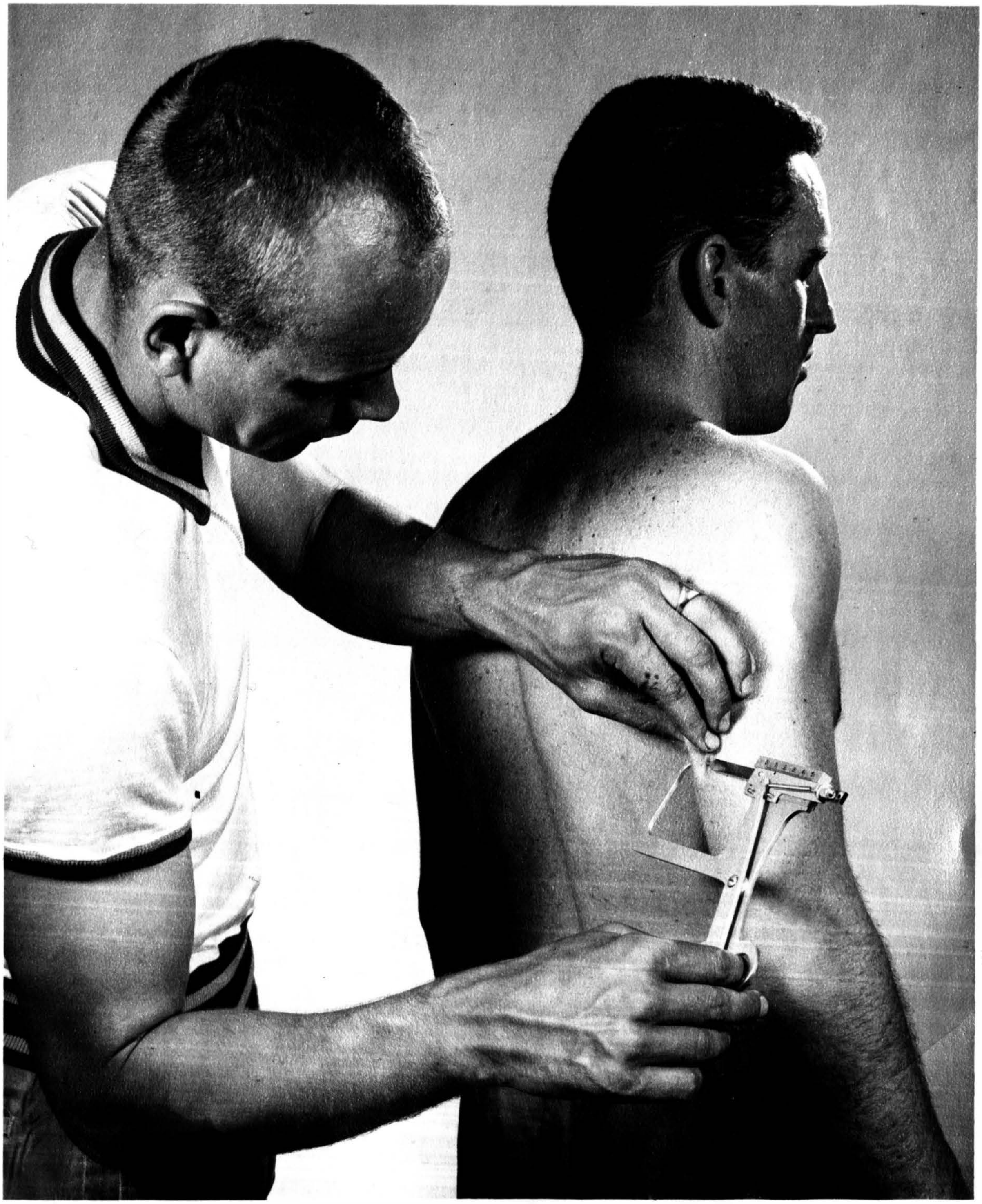

Figure 5. Site D: Measuring Skinfold of the Arm

CHAPTER IV

TREATMENT AND ANALYSIS OF DATA

Processing Data

The basic purpose of this study was to determine the changes in body fat as computed from skinfold measurements of track and field athletes during a season of competition and training. Gain or loss of weight was also noted.

The raw scores were treated statistically by computing the means, the differences between the means, the standard errors of the differences and the critical ratios. The expermental design employed in this investigation was the single group method and, because the number in this case was relatively small (23), the "difference method" as described by Garrett was applied in determining the significance of the difference between the two means.[52] These were correlated means inasmuch as the same test was administered to the same group on five different occasions. The two-tailed test of significance was used as it appeared reasonably probable that there might be either a gain or loss of subcutaneous body fat, and there could be a fluctuation either way in weight. As 22 degrees of

---

[52]Henry E. Garrett, "The Significance of the Difference Between Means and Other Statistics", Statistics in Psychology and Education, 5th Ed., pp. 226-227, Longmans, Green and Company: New York, 1958.

freedom (N-1) remained constant throughout the study, t values of 2.07 and 2.82 were necessary for significance at the five percent and the one percent level of confidence, respectively.[53]

Analysis of Results

In reference to Table I the difference between means, standard error of the difference and critical ratios, computed from the initial and second skinfold measurements may be seen.

TABLE I. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE INITIAL AND SECOND SKINFOLD MEASUREMENTS

25

	M_1 Initial	M_2 Second	Diff. (M_2-M_1)	σ Diff.	t
Chest	.34	.29	-.05	.017	2.94
Cheek	.67	.59	-.08	.022	3.63
Abdomen	.66	.57	-.09	.029	3.10
Arm	.56	.47	-.09	.020	4.50
Weight	163.26	162.31	-.95	.277	3.42

The null hypothesis was rejected at the one percent level of confidence for all skinfold sites and the weight loss which occurred between the initial and second tests. The t values of all the differences exceeded 2.82, thus the losses were significant.

---

[53]Ibid., p. 449.

The difference between means, standard error of the difference and critical ratios of the first and third skinfold tests are shown in Table II.

TABLE II. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE INITIAL AND THIRD SKINFOLD MEASUREMENTS

	M_1 Initial	M_2 Third	Diff. (M_2-M_1)	σ Diff.	t
Chest	.34	.28	-.06	.020	3.00
Cheek	.67	.55	-.12	.018	6.66
Abdomen	.66	.58	-.08	.029	2.75
Arm	.56	.45	-.11	.022	5.00
Weight	163.26	163.69	.43	.601	.72

The null hypothesis was rejected at the one percent level of confidence for skinfold losses of the chest, cheek, and arm. The *t* values of these three skinfold measurements differences were larger than 2.82. There was no significant weight change between the initial and third tests as the *t* value of the mean difference (.72) did not represent significance. A mean difference of abdominal tissue loss of .08 cm. was significant at the five percent level as the *t* value of 2.75 exceeded 2.07. However, this loss could not be recognized as real at the one percent level of confidence.

The difference between the means, standard error of the difference and critical ratios of the first and fourth skinfold

tests are listed in Table III.

TABLE III. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE INITIAL AND FOURTH SKINFOLD MEASUREMENTS

	M_1 Initial	M_2 Fourth	Diff. (M_2-M_1)	σ Diff.	t
Chest	.34	.26	-.08	.018	4.44
Cheek	.67	.49	-.18	.021	8.09
Abdomen	.66	.51	-.15	.036	4.10
Arm	.56	.41	-.15	.021	7.14
Weight	163.26	162.39	-.87	.476	1.82

All t values of the skinfold mean differences for the four measurements were above 2.82. Consequently, the null hypothesis was refuted at the one percent level of confidence. There was no true weight change as the mean difference, -.87, was not significant at the five percent level of confidence.

Table IV refers to the difference between the means, standard error of the difference and critical ratios of the initial and fifth skinfold tests.

TABLE IV. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE INITIAL AND FIFTH SKINFOLD MEASUREMENTS

	M_1 Initial	M_2 Fifth	Diff. (M_2-M_1)	σ Diff.	t
Chest	.34	.25	-.09	.018	5.00
Cheek	.67	.52	-.15	.023	6.52
Abdomen	.66	.49	-.17	.037	4.59
Arm	.56	.39	-.17	.024	7.08
Weight	163.26	160.69	-2.57	.403	6.37

As Table IV refers to the largest span of time, five months, between measurements it was probable that if any significant loss would occur through track training it would be seen in this interval. The null hypothesis was discarded as all five losses were significant at the one percent level of confidence.

The difference between means, standard error of the difference and critical ratios computed from the second and third skinfold measurements are shown in Table V.

TABLE V. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE SECOND AND THIRD SKINFOLD MEASUREMENTS

	M_1 Second	M_2 Third	Diff. (M_2-M_1)	σ Diff.	t
Chest	.29	.28	-.01	.010	1.00
Cheek	.59	.55	-.04	.018	2.22
Abdomen	.57	.58	.01	.018	.55
Arm	.47	.45	-.02	.022	.95
Weight	162.31	163.69	1.38	.567	2.43

There is a marked departure in Table V from the results of the tests illustrated in the previous tables. The chest, abdomen, and arm had no significant change in measurement. The t value for the mean difference of the cheek, 2.22, was above 2.07 and significant at the five percent level, but not true at the one percent level of confidence. A mean weight gain of 1.38 pounds was significant at the five percent level, as the t value of the difference was 2.43, but not high enough to be significant at the one percent level of confidence.

Table VI refers to the difference between means, standard error of the difference and critical ratios computed from the second and fourth measurements.

TABLE VI. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE SECOND AND FOURTH SKINFOLD MEASUREMENTS

	M_1 Second	M_2 Fourth	Diff. (M_2-M_1)	σ Diff.	*t*
Chest	.29	.26	-.03	.008	3.61
Cheek	.59	.49	-.10	.018	5.55
Abdomen	.57	.51	-.06	.020	3.00
Arm	.47	.41	-.06	.020	3.00
Weight	162.31	162.39	.08	.736	.10

The null hypothesis was denied as the *t* values of the mean differences of the chest, cheek, abdomen, and arm measurements were all significant at the one percent level of confidence. An actual mean body weight gain of .08 pounds was not statistically significant as the *t* value of the difference, .10, was below 2.07.

The difference between means, standard error of the difference and critical ratios computed from the second and fifth month skinfold measurements are referred to in Table VII.

TABLE VII. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE SECOND AND FIFTH SKINFOLD MEASUREMENTS

	M_1 Second	M_2 Fifth	Diff. (M_2-M_1)	σ Diff.	*t*
Chest	.29	.25	-.04	.010	4.00
Cheek	.59	.52	-.07	.014	5.00
Abdomen	.57	.49	-.08	.019	4.21
Arm	.47	.39	-.08	.026	3.07
Weight	162.31	160.69	-1.62	.724	2.23

The null hypothesis was discarded for all skinfold measurements as the *t* values of the mean differences all exceeded 2.82. A *t* value of 2.23, for mean loss of weight, was significant at the five percent level, but not at the one percent level of confidence.

Table VIII illustrates the difference between means, standard error of the difference and critical ratio computed from the third and fourth skinfold measurements.

TABLE VIII. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIO COMPUTED FROM THE THIRD AND FOURTH SKINFOLD MEASUREMENTS

	M_1 Third	M_2 Fourth	Diff. (M_2-M_1)	σ Diff.	t
Chest	.28	.26	-.02	.009	2.22
Cheek	.55	.49	-.06	.013	4.61
Abdomen	.58	.51	-.07	.017	4.11
Arm	.45	.41	-.04	.012	3.33
Weight	163.69	162.39	-1.30	.605	2.14

The skinfold fat losses of the cheek, abdomen, and arm were all statistically significant as the t values of the three measurements, 4.61, 4.11, and 3.33, respectively, all exceeded 2.81. Loss of weight and subcutaneous chest fat were significant at the five percent level as the t values of the mean differences, 2.14 and 2.22, respectively, were above 2.07. These losses were not true at the one percent level of confidence.

Table IX lists the difference between means, standard error of the difference and critical ratios of the third and fifth month of skinfold measurements.

TABLE IX. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE THIRD AND FIFTH SKINFOLD MEASUREMENTS

	M_1 Third	M_2 Fifth	Diff. (M_2M_1)	σ Diff.	t
Chest	.28	.25	-.03	.011	2.72
Cheek	.55	.52	-.03	.015	2.00
Abdomen	.58	.49	-.09	.024	3.75
Arm	.45	.39	-.06	.012	5.00
Weight	163.69	160.69	-3.00	.751	3.99

There was a significant loss of weight and adipose tissue of the abdomen and the arm. The t values of all three mean differences were above 2.82 and thus significant at the one percent level of confidence. The null hypothesis was rejected at the five percent level and accepted at the one percent level of confidence for the subcutaneous tissue of the chest and cheek. The t values of the mean differences were larger than 2.07, but smaller than 2.82.

The difference between means, standard error of the difference and critical ratios computed from the fourth and last skinfold measurements are referred to in Table X.

TABLE X. DIFFERENCE BETWEEN MEANS, STANDARD ERROR OF THE DIFFERENCE AND CRITICAL RATIOS COMPUTED FROM THE FOURTH AND FIFTH SKINFOLD MEASUREMENTS

	M_1 Fourth	M_2 Fifth	Diff. (M_2-M_1)	σ Diff.	t
Chest	.26	.25	-.01	.007	1.42
Cheek	.49	.52	.03	.014	2.42
Abdomen	.51	.49	-.02	.012	1.66
Arm	.41	.39	-.02	.009	2.22
Weight	162.39	160.69	-1.70	.528	3.21

The loss of weight experienced by the trackmen was significant at the one percent level of confidence as the *t* value of the mean difference was 3.21. The skinfold loss of subcutaneous tissue of the arm was significant at the five percent level of confidence but not at the one percent level, as the *t* value of the mean difference, 2.22, was larger than 2.07 but smaller than 2.82. The null hypothesis was accepted for both the mean differences of the chest and abdomen measurements. A gain of .03 cm. of the mean of the cheek measurement was significant at the five percent level, but not true at the one percent level of confidence.

Summary and Interpretation

In summarizing the results of the first testing period, January 15 to February 15, adipose tissue losses at all skinfold sites were significant at the one percent level of

confidence. There was also a significant loss of body weight at the one percent level of confidence.

The second month of conditioning and training, February 15 to March 15, resulted in a loss of fat tissue on the arm, significant at the one percent level. A mean weight gain of 1.38 pounds proved to be significant at the five percent level of confidence. Chest, abdomen, and arm skinfold measurements revealed no change of statistical significance. In contrast to the second month's training, the interval from January 15 to March 15, resulted in the athletes losing subcutaneous tissue at the four selected sites. There was also a recorded loss of body weight. Both of these losses were significant at the one percent level of confidence.

The training and conditioning of the trackmen from March 15 to April 15, produced skinfold losses of the cheek, abdomen, and arm significant at the one percent level of confidence. Weight loss was significant at the five percent level. February to April conditioning resulted in skinfold losses at the four sites tested, significant at the one percent level of confidence. An actual body weight gain of .08 pounds was not large enough to be significant at the five percent level.

The final training period was from April 15 to May 15. The abdominal skinfold loss was significant at the five percent level, but not at the one percent level. Weight loss attained significance at the one percent level of confidence. Chest and

arm measurements did not sufficiently change to be significant at the five percent level. The gain in cheek tissue was significant at the five, but not at the one percent level. The interval from January to May produced significant loss of weight and significant skinfold losses at four sites. From February to May, only the weight loss failed to attain significance at the one percent level. It appears that track training was responsible for a significant loss of weight at the one percent level from March until May. Arm and abdominal skinfold losses were significant at the five percent level of confidence. Changes in cheek measurements for this period of time failed to reach the required levels of significance.

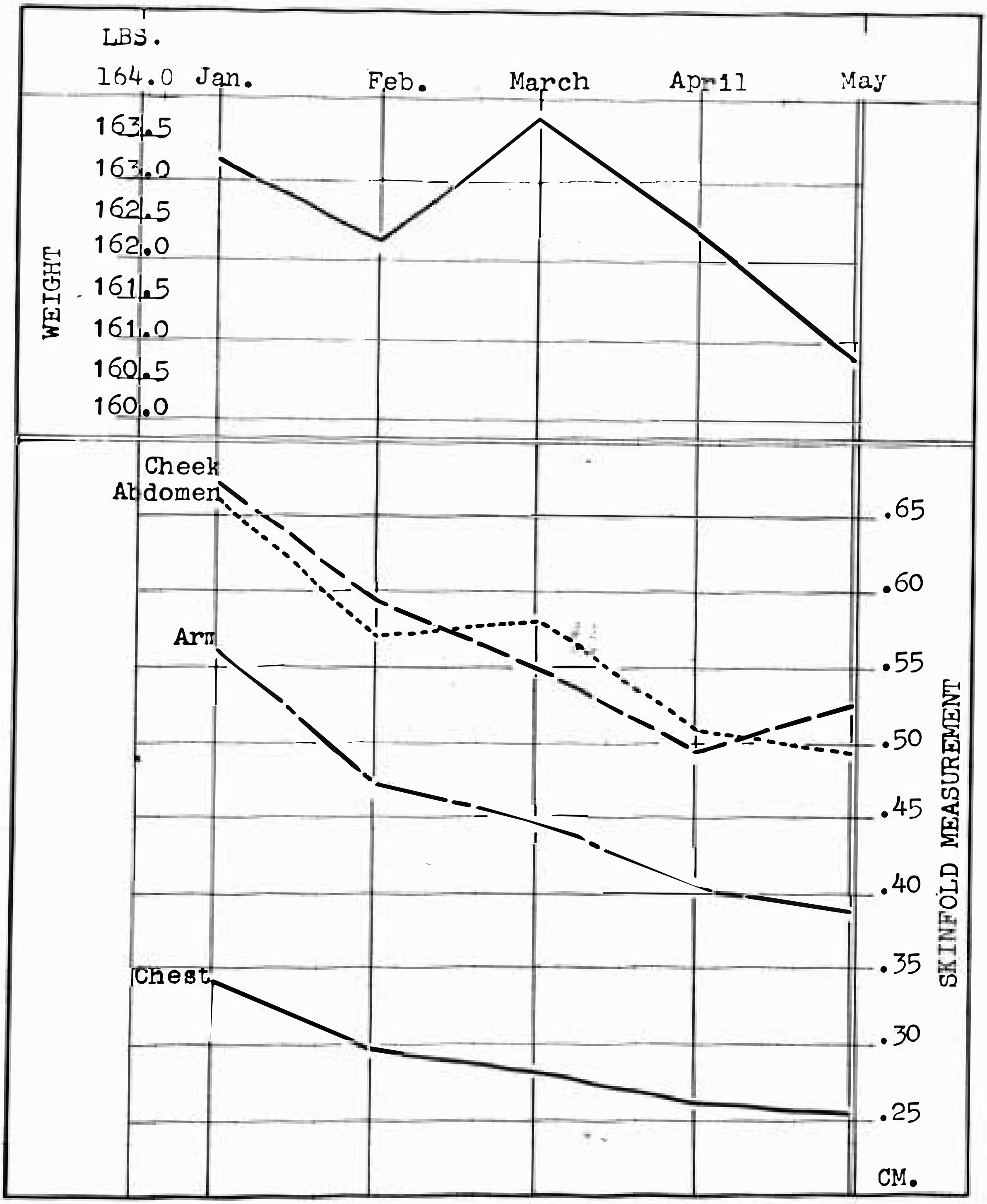

Figure 6. Changes in Skinfold Measurements and in Weight During Track and Field Season

CHAPTER V

IMPLICATIONS AND RECOMMENDATIONS

The basic purpose of this study was to determine the changes in body fat as computed from skinfold measurements of track and field athletes during a season of competition and training. Gain or loss of weight was also recorded.

Within the limitations of this study, the data supports the conclusion that track and field competition and conditioning were responsible for a significant loss of subcutaneous fat and body weight. This conclusion applies to the time elapsed from January to May, the complete length of the study. Shorter periods of training also produced significant skinfold and weight loss. In one instance there was a gain of body weight significant at the five percent level of confidence. This gain, between February and March, might be partially explained by the lack of strenuous activity during this period, in that limited indoor competition may have been detrimental to motivation. The author has no explanation for the gain of cheek tissue from April to May.

The following recommendations are made for skinfold measurements and skinfold testing in future research of this nature:

A. That skinfold calipers be designed and modified so that results from all calipers will be more uniform.

B. That national norms be established for height, weight, and age groups.

C. That further study be made on the validity of the skinfold technique as a method for determining body fat.

D. That studies be extended for longer periods of time and that larger samples be employed.

E. That the effects of training and competition, on changes in subcutaneous fat and gain or loss of body weight, be extended to compare distance runners to sprinters, weight men to jumpers, or other combinations.

F. That skinfold measurements be made on subjects participating in other physical education and athletic activities.

LITERATURE CITED

Barber, Edith M., Cooper, Lenna F., and Mitchell, Helen S., Nutrition in Health and Disease, J. B. Lippincott Company: Philadelphia, Pa., 1943.

Bogert, L. Jean, "Fatty Foods", Nutrition and Physical Fitness, 5th Ed., p. 29, W. B. Saunders Company: Philadelphia, Pa., 1949.

Bookwalter, K. W., and others, "The Relationship of Body Size and Shape to Physical Performance", The Research Quarterly, vol. 23, 271-179, American Association for Health, Physical Education and Recreation: Washington, D. C., October, 1952.

Brozek, J., "Changes of Body Composition in Man During Maturity and Their Nutritional Implications", Federation Proceedings, vol. 11, 785-786, Federation of American Societies for Experimental Biology, Waverly Press, Inc.: Baltimore, Maryland, September, 1952.

Brozek, J., and Keys, A., "Evaluation of Leanness-Fatness in Man: A Survey of Methods", Nutrition Abstracts and Reviews, vol. 20, 248, Commonwealth Bureau of Animal Nutrition, Rowett Research Institute: Bucksburn, Aberdeenshire, Scotland, October, 1950.

______ "Limitations of the Normal Body Weight as a Criterion of Normality", Science, vol. 112, 788, American Association for the Advancement of Science: Washington, D. C., December 28, 1950.

______ "The Evaluation of Leanness-Fatness in Man: Norms and Inter-Relationships", The British Journal of Nutrition, vol. 5, 194-204, Cambridge at the University Press: London, 1951.

______ "Body Build and Body Composition", Science, vol. 116, 141-142, American Association for the Advancement of Science: Washington, D. C., August 8, 1952.

Campney, Harry K. Jr., The Effect of a Combined Program of Physical Activity on the Physical Fitness of an Adult Man, p. 135, Unpublished Master's Thesis, University of Illinois, Urbana, Illinois, 1953.

Carlson, Anton J., and Johnson, Victor, "The Unit of Structure and Function—The Cell", The Machinery of the Body, p. 16, The University of Chicago Press: Chicago, Illinois, 1948.

Cheraskin, E., and Langley, L. L., "Absorption and Utilization", The Physiology of Man, p. 425, McGraw-Hill Book Company, Inc.: New York, 1954.

Cureton, Thomas K., "Body Build as a Framework of Reference for Interpreting Physical Fitness and Athletic Performance", The Research Quarterly Supplement, vol. 12, 328-330, American Association for Health, Physical Education and Recreation: Washington, D. C., May, 1941.

______ Physical Fitness Workbook, p. 120, Stipes Publishing Company: Champaign, Illinois, 1942.

______ "Analysis of the Weight of Champions", Physical Fitness of Champion Athletes, p. 53, University of Illinois Press: Urbana, Illinois, 1951.

______ "Physical Fitness Improvement of a Middle Aged Man, with Brief Reviews of Related Studies", The Research Quarterly, vol. 23, 149-150, American Association for Health, Physical Education and Recreation: Washington, D. C., May, 1952.

______ "The Value of Hard Endurance Exercises and Tests to Produce Changes in Weight, Fat, Metabolism and Cardiovascular Condition", College Physical Education Association, 61st Annual Proceedings, pp. 162-165, American Association for Health, Physical Education and Recreation: Washington, D. C., 1958.

______ "The Effect of Physical Training, Sports, and Exercises on Weight, Fat, and Tissue Proportions", American Academy of Physical Education, Professional Contributions No. 6, pp. 31-37, American Association for Health, Physical Education and Recreation: Washington, D. C., November, 1959.

Franzen, Raymond, "An Analytic Account of Muscle Size and Amount of Subcutaneous Tissue", Physical Measures of Growth and Nutrition, p. 47, Number II of the School Health Monographs, American Child Health Association, J. J. Little Ives Company: New York, 1929.

Garns, S. M., "Comparison of Pinch Caliper and X-Ray Measurements of Skin Plus Subcutaneous Fat", Science, vol. 124, 178-179, American Association for the Advancement of Science: Washington, D. C., July 27, 1956.

Garrett, Henry E., "The Significance of the Difference Between Means and other Statistics", *Statistics in Psychology and Education*, 5th Ed., pp. 226-227, Longmans, Green and Company: New York, 1958.

Gemmill, Chalmers L., "The Fuel for Muscular Exercise", *Physiological Reviews*, vol. 22, 49, American Physiological Society: Baltimore, Maryland, January, 1942.

Grover, G. H., *An Approximate Analysis of Adipose Tissue in Relationship to Nutrition, Condition, and Skeletal Size*, p. 67, Unpublished Master's Thesis, Springfield College: Springfield, Massachusetts, 1936.

Herden, E. L., *The Effects of the Health-Walker Dynamic Exercise Machine on the Physical Fitness of Two Adult Men*, pp. 210-212, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1954.

Hopkins, Richard E., *The Effects of Volleyball and Calisthenics on the Physical Fitness of Two Adult Men*, p. 85, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1951.

Interdepartmental Committee on Nutrition for National Defense, "Clinical Appraisal of Nutriture", *Manual for Nutrition Surveys*, p. 30, U. S. Government Printing Office: Washington, D. C., May, 1947.

Keys, A., and Brozek, J., "Body Fat in Adult Man", *Physiological Reviews*, vol. 33, 249, The American Physiological Society: Washington, D. C., July, 1953.

Kireilis, R. W., *The Relation of Physical Training to Adiposity*, pp. 100-102, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1944.

Kireilis, R. W., and Cureton, Thomas K., "The Relationships of External Fat to Physical Education Activities and Fitness Tests", *The Research Quarterly*, vol. 18, 123-129, American Association for Health, Physical Education and Recreation: Washington, D. C., May, 1947.

Kroll, Walter, "An Anthropometrical Study of Some Big Ten Varsity Wrestlers", *The Research Quarterly*, vol. 24, 308-309, American Association for Health, Physical Education and Recreation: Washington, D. C., October, 1954.

Kristeufek, Charles J., Effect of Endurance Training on an Adult Subject, pp. 82-84, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1951.

Lusk, Graham, "The Influence of Mechanical Work on Metabolism", The Elements of the Science of Nutrition, 4th Ed., p. 446, W. B. Saunders Company: Philadelphia, Pa., 1928.

Mam, Joseph, The Effect of Physical Activity on the Adiposity of Young Boys, pp. 65-67, Unpublished Master's Thesis, University of Illinois: Urbana, Illinois, 1957.

McLester, James S., and Darby, William J., "Obesity and Leanness", Nutrition and Diet in Health and Disease, 6th Ed., p. 334, W. B. Saunders Company: Philadelphia, Pa., 1952.

Mendel, L. B., "Some Relations in Diet to Fat Depositions in the Body", Yale Journal of Biology and Medicine, vol. 3, 107-137, New Haven, Connecticut, October, July, 1930-1931.

Montoye, Henry J., et al, "Weight Analysis", The Longevity and Morbidity of College Athletes, p. 70, Phi Epsilon Kappa Fraternity: East Lansing, Michigan, 1957.

Morehouse, L. E., and Miller, A. T., "Diet", Physiology of Exercise, p. 291, C. V. Mosby Company: St. Louis, Missouri, 1948.

Morehouse, L. E., and Rasch, P. J., "Kinesiological Factors in Athletics", Scientific Basis of Athletic Training, p. 22, W. B. Saunders: Philadelphia, Pa., 1958.

Morse, Minerva, and Schlutz, Frederic W., "Factors Influencing the Concentrations of the Serum Protein, Chloride and Total Fixed Base of the Dog During Exercise", The American Journal of Physiology, vol. 121, 296, American Physiological Society: Baltimore, Maryland, 1936.

Najjar, Victor A., Fat Metabolism, The Johns Hopkins Press: Baltimore, Maryland, 1954.

Pascale, L. R., et al, "Report of Changes in Body Composition of Soldiers During Paratrooper Training", 2937 TU Medical Nutrition Laboratory Report No. 156, United States Army, Fitzsimons Army Hospital: Denver, Colorado, March 22, 1955.

Riedman, Sarah R., "Chemical Dynamics in Muscular Work", The Physiology of Work and Play, p. 87, The Dryden Press: New York, 1952.

Seltzer, C. C., "Chest Circumference Changes as a Result of Severe Physical Training", American Journal of Physical Anthropology, vol. 4, 389-393, The Wistar Institute of Anatomy and Biology: Philadelphia, Pa., September, 1946.

Tanner, J. M., "The Effect of Weight-Training on Physique", American Journal of Physical Anthropology, vol. 10, 458-459, The Wistar Institute of Anatomy and Biology: Philadelphia, Pa., December, 1952.

Thompson, C. W., "Changes in Body Fat, Estimated from Skinfold Measurements of Varsity College Football Players During a Season", The Research Quarterly, vol. 30, 87-90, American Association for Health, Physical Education and Recreation: Washington, D. C., March, 1959.

Thompson, C. W., Buskirk, E. R., and Goldman, R. F., "Changes in Body Fat, Estimated from Skinfold Measurements of College Basketball and Hockey Players During a Season", The Research Quarterly, vol. 27, 418-420, American Association for Health, Physical Education and Recreation: Washington, D. C., December, 1956.

Welham, W. C., and Behnke, A. R., "Specific Gravity of Healthy Men. Body Weight Plus Volume and Other Physical Characteristics of Exceptional Athletes and of Naval Personnel", Journal of the American Medical Association, vol. 118, 498, American Medical Association: Chicago, Illinois, February 14, 1942.

APPENDICES

APPENDIX A

Raw Data for Initial Measurement

Subject No.	Chest	Cheek	Abdomen	Arm	Weight
1.	.33	.60	.53	.45	157
2.	.42	.60	.66	.40	152
3.	.20	.50	.43	.40	142
4.	.28	.63	.48	.63	183
5.	.60	.78	.70	.98	171
6.	.30	.55	.38	.40	142
7.	.35	.70	.60	.96	155
8.	.40	.58	.50	.43	150
9.	.40	.85	.65	.50	165
10.	.40	.87	.82	.47	202
11.	.35	.90	.98	.55	204
12.	.35	.90	.58	.48	158
13.	.30	.82	.40	.35	153
14.	.20	.62	.53	.40	144
15.	.40	.65	1.13	.57	140
16.	.20	.50	.47	.30	149
17.	.32	.60	1.37	.95	206
18.	.63	.95	1.18	1.00	189
19.	.30	.60	.50	.52	149
20.	.42	.76	1.13	1.00	199
21.	.25	.35	.40	.37	150
22.	.30	.70	.42	.43	161
23.	.25	.52	.43	.45	134

APPENDIX B

Raw Data for Second Measurement

Subject No.	Chest	Cheek	Abdomen	Arm	Weight
1.	.30	.50	.50	.28	157
2.	.30	.60	.50	.35	153
3.	.20	.45	.45	.30	142
4.	.22	.57	.57	.47	181
5.	.30	.68	.80	.93	169
6.	.28	.50	.35	.33	143
7.	.27	.67	.57	.55	154
8.	.25	.48	.45	.30	149
9.	.30	.55	.50	.47	163
10.	.35	.80	.77	.50	201
11.	.30	.67	.70	.50	197
12.	.35	.70	.63	.40	156
13.	.25	.55	.45	.30	151
14.	.25	.55	.48	.48	142
15.	.35	.70	.83	.40	140
16.	.25	.50	.45	.30	148
17.	.32	.62	1.00	.65	208
18.	.40	.67	.85	1.00	190
19.	.30	.52	.50	.43	148
20.	.50	.92	.77	.97	198
21.	.25	.40	.35	.30	148
22.	.20	.60	.35	.35	160
23.	.20	.45	.35	.30	135

APPENDIX C

Raw Data for Third Measurement

Subject No.	Chest	Cheek	Abdomen	Arm	Weight
1.	.25	.45	.50	.40	157
2.	.35	.50	.50	.35	156
3.	.25	.40	.40	.35	143
4.	.33	.65	.55	.60	184
5.	.30	.55	.65	.65	177
6.	.25	.40	.40	.35	142
7.	.25	.65	.70	.55	159
8.	.25	.42	.42	.35	150
9.	.25	.55	.60	.40	167
10.	.30	.70	.80	.40	202
11.	.35	.70	.68	.40	203
12.	.30	.68	.52	.40	154
13.	.30	.60	.42	.30	151
14.	.20	.60	.48	.35	142
15.	.37	.50	.77	.50	138
16.	.20	.48	.40	.30	148
17.	.25	.47	1.17	.80	206
18.	.30	.77	.68	.65	190
19.	.30	.60	.48	.47	148
20.	.50	.75	.97	.95	202
21.	.20	.30	.40	.30	150
22.	.35	.63	.40	.35	163
23.	.25	.50	.35	.30	133

APPENDIX D

Raw Data for Fourth Measurement

Subject No.	Chest	Cheek	Abdomen	Arm	Weight
1.	.25	.45	.45	.35	153
2.	.30	.40	.45	.30	151
3.	.20	.42	.40	.30	144
4.	.25	.50	.50	.45	184
5.	.30	.50	.55	.60	168
6.	.27	.50	.40	.33	143
7.	.30	.58	.60	.60	158
8.	.20	.40	.38	.25	151
9.	.25	.60	.50	.35	162
10.	.35	.58	.77	.35	201
11.	.30	.60	.70	.40	202
12.	.25	.60	.45	.35	154
13.	.25	.57	.40	.30	150
14.	.20	.40	.40	.40	138
15.	.28	.38	.55	.42	136
16.	.20	.40	.40	.25	149
17.	.30	.40	.80	.60	204
18.	.30	.60	.70	.70	189
19.	.30	.55	.50	.45	150
20.	.37	.78	.88	.87	201
21.	.20	.30	.35	.25	150
22.	.20	.52	.35	.35	159
23.	.20	.45	.35	.30	138

APPENDIX E

Raw Data for Fourth Measurement

Subject No.	Chest	Cheek	Abdomen	Arm	Weight
1.	.25	.45	.40	.30	152
2.	.25	.50	.40	.30	151
3.	.20	.35	.45	.32	145
4.	.20	.55	.55	.55	187
5.	.20	.55	.52	.52	164
6.	.25	.40	.33	.30	140
7.	.23	.65	.58	.60	156
8.	.20	.40	.35	.25	147
9.	.25	.53	.38	.30	161
10.	.35	.63	.75	.35	200
11.	.30	.68	.65	.35	198
12.	.35	.65	.45	.30	150
13.	.25	.60	.35	.25	147
14.	.20	.53	.38	.35	138
15.	.30	.50	.55	.40	134
16.	.20	.40	.40	.20	148
17.	.25	.50	.75	.60	201
18.	.30	.50	.85	.60	192
19.	.30	.57	.50	.45	150
20.	.30	.83	.75	.75	197
21.	.20	.25	.35	.30	142
22.	.22	.58	.35	.30	159
23.	.25	.48	.35	.30	137

TYPED BY CAROL A. EISENBRAUN