MAXIMAL WORK CAPACITY AS RELATED TO STRENGTH, BODY COMPOSITION, AND PHYSICAL ACTIVITY IN YOUNG WOMEN

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By

Doris Darwick

AN ABSTRACT OF A THESIS

Submitted to
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ABSTRACT

MAXIMAL WORK CAPACITY AS RELATED TO STRENGTH, BODY COMPOSITION, AND PHYSICAL ACTIVITY IN YOUNG WOMEN

by Doris Darwick

The relationship of physical activity, strength, and body composition to the maximal work capacity of young women was studied. Twenty-eight college women, age 18 to 22, were measured to determine their: (a) body composition by assessing body fat and calculating fat-free body weight from the predicted specific gravity, (b) habitual physical activity by means of an activity history recall questionnaire, (c) strength using the cable tensiometer in the measurement of eleven positions, and (d) maximal work capacity by determining the maximal oxygen consumption in a graded treadmill test.

Gross body weight and fat-free body weight were found to correlate .64 (r) with maximal oxygen consumption. Body weight and fat-free body weight correlated .69 and .62, respectively, with the daily caloric expenditure estimated from the recall questionnaire data. Maximal oxygen intake correlated .51 with hip flexion and .50 with knee extension. The best strength measures to indicate total strength were hip flexion (.88), knee extension (.84), and elbow flexion (.83).

Active subjects as rated from the recall questionnaire were: (a) heavier and possessed a greater fat-free body weight, (b) found to expend more energy per day, (c) capable of higher maximal oxygen consumptions, and (d) stronger in total and trunk extension strength.

Physical education majors as a group had higher fat-free body weights, expended more energy per day, were capable of higher maximal oxygen intakes, and were consistently stronger than the non-physical education majors.

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The author wishes to extend sincere thanks to Dr. Janet A. Wessel for her invaluable assistance and encouragement.

DEDICATION

Dedicated to my family for their love, faith, and prayers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

"And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul."[1] Oxygen is necessary not only to life itself but to every act of human performance; mental and physical actions are dependent upon oxygen supply to the working tissues. Bard stated that "maximal oxygen consumption is probably the best single physiological indicator of a man's capacity for maintaining extremely hard work."[2] According to Astrand and Rhyming, "the individual's capacity: (or fitness) for heavy prolonged muscular work will first of all be dependent on the supply of oxygen to the working muscles. In types of work which engage large groups of muscle the limiting factor for the maximal oxygen intake (aerobic capacity) will probably be the capacity and regulation of the oxygen transporting system."[3] Astrand

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[1]Genesis, 2:7.

[2]Phillip Bard (ed.), Medical Physiology (11th ed.; St. Louis: The C. V. Mosby Company, 1961), p. 498.

[3]P. O. Astrand and Irma Rhyming, "A Nonogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7:118, July, 1954 to May, 1955.

believes that "it is of essential physiological interest to know a) the maximal activity level of the normal healthy human and how this level varies with sex and age; b) the factors normally limiting this upper level and, therefore, the physical performance."[4]

As the human body is designed for action it is evident that physical work capacity should be assessed during muscular work; preferrably to determine maximal work during maximal performance. Because of natural endowed physical capacities and anatomical structure, performance, although relatively constant in one individual, varies considerably between individuals. It is apparent that sex, age, body composition, inherent skills, and similar factors all influence the physical work capacity of the individual. Just what level of physical work capacity is necessary and/or desirable for general health is not yet known. It is generally agreed, however, that an individual should possess a work capacity level above that which is necessary to carry on their daily activities. It is the objective of this study to contribute to the better understanding of physical work capacity of young women and the individual variations as influenced by strength, body composition, and physical activity.

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[4]P. O. Astrand, "Human Physical Fitness With Special Reference to Sex and Age," Physiological Reviews, 36:380, July, 1956.

Purpose of the Study

This study was designed with the intent of determining the relationship of physical activity, strength, and body composition to the maximal work capacity of young women.

In order to realize this purpose four main objectives were selected:

1. to determine maximal oxygen capacity of young women,
2. to determine the effect of body composition on maximal oxygen consumption,
3. to determine the relationship of strength and maximal oxygen consumption, and
4. to determine the differences between active and less active individuals in relation to maximal oxygen consumption.

Need for the Study

The literature reveals only a few studies on women concerning maximal work capacity as related to age and body composition and none relating physical activity or strength to maximal work capacity. Contributions of basic information in the analysis of human biological individuality are essential if man is to gain:

a. understanding of human difference,
b. understanding of fitness and efficiency of performance,

c. understanding of activity programs and procedures to increase the effectiveness thereof.

Limitations of the Study

Sample.

1. The number of subjects in the sample were limited to twenty-eight women.
2. All subjects were college women 18 to 22 years of age.
3. All subjects were volunteers.

Techniques and procedures.

1. The design of the study was limited in that each of the subjects participating could not follow a definite order and sequence in testing and re-testing.
2. The physical activity history recall questionnaire was based on the subjects individual record of activities for a limited period of five days.
3. Very little research evidence was available on ways to assess maximal work capacity of women or levels of performance.

Definition of Terms

Per cent of standard weight (relative body weight).[5] Per cent of standard weight was calculated by dividing the

[5] Build and Blood Pressure Study, 1959, Vol. I (Chicago: Society of Actuaries, 1959).

predicted weight into the actual weight. The predicted weights were obtained from the Build and Blood Pressure Study.

Predicted specific gravity.[6] Specific gravity was predicted by using the following formula:

$$\text{Specific gravity} = 1.0884 - .0004231_{X1} - .0003401_{X13}$$

Where X1 = skinfold on mid-abdominal line halfway between the umbilicus and the pubis. (in mm)

X13 = percentage "standard" weight (average weight per height and age).

Per cent of fat of body weight.[7] Body fat content was calculated from densiometrically determined specific gravity using the Rathbun and Pace formula:

$$\text{Per cent fat} = 100 \left(\frac{5.548}{\text{Specific Gravity}} - 5.044\right)$$

Fat-Free body weight. Fat-free body weight was computed by subtracting the calculated fat content from the body weight.

Ponderal index. Ponderal index was computed by dividing height by the cube root of weight.

$$\frac{\text{Height}}{\sqrt[3]{\text{Weight}}}$$

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[6] Charlotte Young, Elizabeth Martine, Rosalinda Tensuan, and Joan Blondin, "Predicting Specific Gravity and Body Fatness in Young Women," Journal of the American Dietetic Association, 40:105, February, 1962.

[7] E. N. Rathbun and N. Pace, "Body Composition I," Journal of Biological Chemistry, 158:675, 1945.

Physical activity. All subjects completed an activity history recall questionnaire in which they recorded their activity for a consecutive five day period. Energy expenditure; i.e., physical activity, was determined by the computation of the subject record.

Maximal work capacity. Maximal oxygen consumption was determined during a "run" on the treadmill at 6 mph with a one per cent grade increase each minute until the subject was unable to continue. The "run" was preceded by a ten minute warm up "walk" at 3.5 mph on zero grade.

CHAPTER II

REVIEW OF LITERATURE

In order to develop a complete review of the literature pertaining to this study, it was necessary to consider several aspects of investigation. The several topics involved will be treated as separate areas of review and will appear under separate headings.

Studies Concerning Methods for Determining Body Composition and Specific Gravity

Young[8] and her associates reported a pilot study designed to obtain normative data on the lean body mass and fatness of a representative sampling of 94 Cornell University women 17 to 30 years of age. The authors were interested in studying the interrelationships existing between estimates of lean body mass and/or adiposity based on determinations in each of body density, total body water, skinfold measurements, fat-pat measurements from soft tissue x-rays, anthropometric measures, creatine excretion, and basal oxygen consumption.

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[8] C. M. Young, M. E. Martin, M. McCarthy, M. J. Marniello, E. Harmuth, and J. Feyer, "Body Composition of Young Women," Journal of the American Dietetic Association, 38:332-340, April, 1961.

The authors findings[9] on body weight, fat-free body weight, per cent body fat, and specific gravity are presented in Table I.

TABLE I

WEIGHT, PER CENT BODY FAT, AND SPECIFIC GRAVITY AS DETERMINED IN YOUNG'S STUDY

Characteristic	Range	Mean	S.D.
Weight (kg)	44.11 - 76.20	58.96	6.445
Fat-free body weight (kg)	31.94 - 61.11	42.15	6.073
Per cent body fat (Rathbun-Pace)	15.81 - 38.62	28.69	4.856
Specific gravity	1.0217-1.0665	1.0408	0.0094

The authors further stated that the "pubis" measurement correlated best of all measurements with both total skinfold thickness (r=.90) and density (r= -.66).

Young[10] and her associates in a more recent article published a predictive equation for specific gravity. Intercorrelations between skinfolds, with total skinfold thickness and with density, were obtained. Using the

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[9] *Ibid*., p. 335.

[10] Young, *et al*., *op. cit*., 102-107.

skinfold measurements obtained in their earlier study,[11] linear regression equations were formulated to predict specific gravity. After numerous computations the authors found that when a standard weight was included as a variable there was no significant difference in predicting specific gravity using only one skinfold. The pubis skinfold used in this formula had the best correlation with both total skinfold thickness (r = .90) and density (r = -.66) as reported in the previous study. The following equation was formulated for predicting specific gravity.[12]

$$\text{Specific gravity} = 1.0884 - .0004231_{X1} - .0003401_{X13}$$

When X_1 = skinfold on the mid-abdominal line halfway between the umbilicus and the pubis (in mm).

X_{13} = percentage "standard" weight (average weight per height and age).

The correlation between determined and predicted specific gravity based on this equation was r = .70; standard deviation of differences was 0.0068 units. This was found to be approximately 3.4 per cent body weight as fat.

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[11] Ibid.

[12] Ibid., p. 105.

Studies Concerning Maximal Oxygen Consumption as Related to Body Composition

Mahadeva, Passmore, and Woolf[13] investigated the relationship between energy expenditure during standardized walking and stepping, and weight, height, race, and sex in 50 subjects. Energy expenditure was found to be closely correlated with body weight, but was not significantly correlated with height, age, race, or sex. The authors concluded that in any physical activity in which a large proportion of energy expenditure is used to move the body the metabolic cost will be directly proportional to the body weight.

Seltzer[14] measured the oxygen intake of 34 male students, aged 20 to 38 years, during a maximal two to five minute run on the treadmill. The mean maximal oxygen uptake was 3.35 liters per minute. A number of anthropometric measurements were correlated with energy expenditure. Maximal oxygen uptake per minute correlated with stature ($r = .59$ and with weight ($r = .88$).

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[13] K. Mahadeva, R. Passmore, and B. Woolf, "Individual Variations in the Metabolic Cost of Standardized Exercises: The Effects of Food, Age, Sex, and Race," Journal of Physiology, 121:225-231, 1953.

[14] Carl C. Seltzer, "Body Build and Oxygen Metabolism at Rest and During Exercise," American Journal of Physiology, 129:1-13, 1940.

Buskirk and Taylor[15] studied the relationships between maximal oxygen intake and components of body composition. Fifty-nine young college students and soldiers participated in the experiment. The following correlation coefficients were obtained: maximal oxygen intake with body weight r = .63, maximal oxygen intake with fat-free body weight r = .85, maximal oxygen intake with "active tissue" r = 91, and maximal oxygen intake with blood volume r = .78. They defined "active tissue" as body weight minus estimated body fat (densitometry), thiocyanate space and bone mineral (7 per cent of fat-free body weight). The subjects were also divided into three groups of nine relatively sedentary students classified according to the percentage of body fat (less than 10, 10-25, and 25 and above). Each group was compared with respect to the maximal amount of oxygen used per minute per kilogram of fat-free body weight. The authors found no observable difference existing between the groups.

Von Dobeln[16] investigated the relationships between maximal oxygen intake, total hemoglobin, and (body weight minus adipose tissue) 2/3. In all, 33 male and 32 female subjects participated in the study. For each subject,

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[15]E. Buskirk and H. Taylor, "Relationships Between Maximal Oxygen Intake and Components of Body Composition," Federation Proceedings, 13:21, March-December, 1954.

[16]Wilhelm Von Dobeln, "Maximal Oxygen Intake, Body Size and Total Hemoglobin in Normal Man," Acta Physiologica Scandinavica, 38:193-199, September, 1956.

total hemoglobin, per cent fat based on hydrostatic weighing, and maximal oxygen consumption per unit of time was obtained. Maximal oxygen intake values were plotted against the respective values for body weight minus adipose tissue. A correlation coefficient of r = .76 was reported between (weight minus adipose tissue) 2/3 and maximal oxygen intake.

Von Dobeln[17] administered a maximal oxygen uptake test to 35 men and 35 women to determine the differences in maximal oxygen uptake as related to body composition. The mean maximal uptake for men was 3.91 liters per minute and for the women 3.06 liters per minute. The mean weight of the men was 69.3 kilograms and of the women 62.8 kilograms; however, the men at a ten per cent higher body weight attained a twenty-eight per cent higher maximal oxygen uptake than the women. Von Dobeln concluded that there was not a linear relationship between body size and maximal oxygen intake. The author suggested that the difference in maximal metabolic rate between the sexes was due to the difference in the hemoglobin content of the blood. The mean hemoglobin content of the men was 14.95 g/100 ml. and in the women 13.47 or ten per cent less.

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[17]Wilhelm Von Dobeln, "Human Standard and Maximal Metabolic Rate in Relation to Fat-Free Body Mass," Acta Physiologica Scandinavica, Vol. 37, Supplementum 126:3-38, 1956.

Welch, Riendeau, Crisp, and Isenstein[18] studied the relationship of maximal oxygen consumption to various components of body composition in 28 healthy young men. The authors stated that on the basis of previous studies conducted by Taylor and Buskirk,[19] and Von Dobeln,[20] the assumption was that oxygen was more highly related to lean tissue than to any other description of body composition. "One can infer from the correlations reported that maximum oxygen consumption is dependent mainly on the amount of lean tissue in the body."[21]

The subjects used in this study were tested on the treadmill at grades of 6, 8.5, and 11 per cent. The time of the runs was 2 minutes and 45 seconds. Maximal oxygen consumption was considered to be attained when running at the next higher grade did not increase the maximal oxygen consumption by more than 150 cc. above the previous grade. Significant correlations ($P < 0.01$) between maximal oxygen consumption in liters per minute and body weight ($r = .59$); body weight minus fat ($r = .65$); and body weight minus bone ($r = .64$) were obtained. The authors emphasized that the

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[18] B. E. Welch, R. P. Riendeau, C. E. Crisp, and R. S. Isenstein, "Relationship of Maximal Oxygen Consumption to Various Components of Body Composition," Journal of Applied Physiology, 12:395-398, May, 1958.

[19] Taylor and Buskirk, *loc. cit.*

[20] Von Dobeln,

[21] Welch, *et al.*, *loc. cit.*

correlations obtained by Taylor and Buskirk,[22] and Von Dobeln[23] can be interpreted in that from 53 to 83 per cent of the variability in maximal oxygen consumption may be attributed to variations in the percentage of lean body mass. Welch and his associates concluded that the percentage of fat in the body had no significant influence on the maximal oxygen consumption when expressed as either liters per minute or cubic centimeters per minute per kilogram of fat-free body weight. Significant differences were found when maximum oxygen consumption was expressed as cubic centimeters per minute per kilogram of weight. The authors suggested that although fat may not have an effect on the ability of the tissues to extract oxygen, it did have a significant effect on the circulatory capacity of the individual. This was due to the fact that fat increased weight, and therefore, the energy requirement. However, there was not a corresponding increase in the maximum oxygen intake.

Studies Concerning Methods and Procedures for Determining Maximal Oxygen Consumption

Johnson, Brouha, and Darling[24] discussed methods and procedures used to determine an adequate test of fitness

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[22]Taylor and Buskirk, loc. cit.

[23]Von Dobeln,

[24]R. E. Johnson, L. Brouha, and R. C. Darling," A Test of Physical Fitness for Strenuous Exertion," Revue Canadienne De Bilogic, 1:491-503, June, 1942.

for strenuous exertion. The same investigators concluded that hard work must be used to determine hard work if hard work is in question as differences between fit and unfit individuals during submaximal work are arithmetically smaller at lower metabolic rates.

The authors stated that the type of exercise used is not important provided that it:

a. stresses the cardio-vascular system by involving large muscle groups,

b. is of such intensity that it exhausts one-third of all the subjects within five minutes, and

c. does not demand any unusual skill for successful performance.

The authors further postulate that all subjects should work at a rate linearly proportional to their body weight. The reactions of the fit and unfit individual of the same weight to the same maximal work differ in that the fit individual will consume more oxygen, attain a lower maximal heart rate, and will endure longer before reaching exhaustion.

Taylor, Buskirk, and Henschel[25] examined maximal oxygen consumption methods and procedures by running several

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[25] H. L. Taylor, E. Buskirk, and A. Henschel, "Maximal Oxygen Intake as an Objective Measure of Cardio-Respiratory Performance," Journal of Applied Physiology, 8:73-80, July, 1955 to May, 1956.

experiments on the motor driven treadmill. Data was collected on 27 soldiers and 46 student males between the ages of 18 and 35.

The warm-up consisted of walking at 3.5 mph on a 10 per cent grade for ten minutes to one hour. Within five minutes or less of completing the walk, the subject started running at 7 mph for three minutes. The subject repeated the test procedure on three successive days with a grade increase of 2.5 per cent each day.

The authors found that using a constant speed (7 mph) and increasing the grade in steps of 2-1/2 per cent was more satisfactory than using a constant grade and increasing the speed. The increase in oxygen consumption, associated with an increase of 2-1/2 per cent grade (below maximal oxygen intake), was approximately 300 cc/minute. If the oxygen intake at two different grades differed by less than 150 cc/minute or 2.1 cc/kgm of body weight per minute, they assumed that a maximal oxygen intake had been obtained.

Increasing the working muscle mass by simultaneous running and arm work increased the maximal oxygen intake. Therefore the same investigators concluded that maximal oxygen intake was only maximal under specific working conditions. The authors further postulate that after maximal oxygen had been reached changes in speed or grade of the treadmill did not change the oxygen intake. It appeared to the authors that as long as changes in grade running skill did not change the muscle mass used for this purpose that maximal oxygen intake must be independent of skill.

The coefficient of reliability for these procedures was 0.95 in 69 test-retest determinations.

Studies Concerning Responses to Maximal Work Capacity of Men and Women

Metheny and associates[26] determined physiologic responses of men and women to strenuous work on the motor driven treadmill. The subjects consisted of 17 women between the ages of 19 and 27 and 30 men between the ages of 19 and 23. The exercise consisted of running at 7 mph on an 8.6 per cent grade for five minutes or until unable to continue. During maximal work the average run for the women was only half that of the men before becoming exhausted. The women attained a maximal oxygen consumption of 40.9 cc/kg/min., a maximal R.Q. of 1.06, and a maximal heart rate of 197/min. The men attained 51.3 cc/kg/min., 1.14, and 194/min. respectively.

In a study by Astrand[27] 44 physically active female subjects 20 to 65 years of age were examined three to seven

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[26] E. Metheny, L. Brouha, R. E. Johnson, and W. H. Forbes, "Some Physiologic Responses of Men and Women to Moderate and Strenuous Exercise: A Comparative Study," American Journal of Physiology, 137:318-326, August-November, 1942.

[27] Irma Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, Vol. 49, Supplementüm, 169:11-87, 1960.

different days when cycling at submaximal to maximal loads. Heart rate, pulmonary ventilation, and oxygen uptake were determined during work and blood lactate concentration was measured after each work load.

I. Astrand and P. O. Astrand administered various maximal work capacity tests to women of many ages. Metabolic responses concerning the age ranges pertinent to the present study are presented in Table II.

TABLE II

METABOLIC RESPONSES

Age	Number of Subjects	Maximal 02 l/ Minute	Maximal 02 ml/ kg/min.	Maximal Heart Rate	Oxygen Pulse
20-29	8	2.23 ± .09	39.9±1.66	187 ± 3.4	11.9 ± .45
20-25 P.O. Astrand	32	2.88 ± .04	48.4± .49	199 ± 1.8	--
20-25 P.O. Astrand 1952	44	2.90 ± .04	48.4± .50	198 ± 1.5	--

Maximal oxygen uptake was indicated by: (a) an oxygen uptake which did not increase despite a rising work load, but reached a level and/or two liters and (b) a blood lactate concentration which was high, 90-100 mg per 100 ml, after work of at least four minutes duration. Oxygen uptake at certain loads was somewhat smaller for younger subjects. Women had a lower oxygen uptake than men at a fixed work load but calculated mechanical efficiency was identical. At lower loads (300 rpm/minute) the mechanical efficiency was significantly lower for older than younger subjects. Mechanical efficiency decreased from about twenty-five to eleven per cent when decreasing the load from 450 to 50 rpm per minute. A rectilinear relationship between oxygen uptake per minute and pulmonary ventilation per minute and also an approximate rectilinear relationship between heart rate and oxygen uptake per minute was found in all age groups.

Astrand classified aerobic work capacity into norms to evaluate work capacity. The figures used to evaluate women of normal body weight aged 20-29 are presented in Table III.[28]

TABLE III

AEROBIC WORK CAPACITY, OXYGEN 1; ml/kg

Low	Fair	Average	Good	High
≤ 1.69	1.70-1.99	2.00-2.49	2.50-2.79	2.80 ≥
≤ 28	29-34	35-43	44-48	49 ≥

[28] Ibid., p. 83.

Studies Concerning Responses to Maximal Work Capacity of Men

Taylor[29] administered a submaximal and maximal treadmill test twice to 31 male college students ranging in age from 19 to 26. The test consisted of a four minute walk on the treadmill; 108 meters per minute at a grade of 5 per cent, and a run to exhaustion; 162 meters per minute set at the initial grade of 5 per cent elevated one per cent each minute until time of subject exhaustion. The test and retest were three days apart. The mean maximal values attained were heart rate; 198 per minute, and oxygen in liters per minute; 3.48. The test-retest correlations were $r = .81$ and $r = .70$ respectively.

During the submaximal test per cent oxygen correlated positively with time run while body weight and carbon dioxide were insignificantly correlated. However, the responses (heart rate, respiratory rate, ventilation, and blood lactate) to the maximal test were insignificantly correlated with time run. Taylor stated that this evidence revealed that each subject ran to his individual maximal value which had little relation to his fitness; the length of the time he was able to run being the essential value.

In submaximal exercise the oxygen consumption correlated with body weight $r = .71$ and with weight partialled

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[29]Craig Taylor, "Some Properties of Maximal and Submaximal Exercise with Reference to Physiological Variation and the Measurement of Exercise Tolerance," American Journal of Physiology, 142:200-212, August to December, 1944.

out r = .23. In maximal exercise the oxygen consumption correlation dropped to r = .43 and with weight partialled out rose to r = -.46. Taylor concluded that in submaximal exercise oxygen consumption is chiefly a function of body weight and only slightly related to fitness but that in maximal exercise the relation with weight drops and the fitness criterion increases considerably.

Heart rate and blood lactate were found to be the most reliable submaximal measures but were approximated in maximal work by per cent oxygen and oxygen consumption. Ventilation was of low reliability in both submaximal and maximal work, while respiration became highly reliable in the maximal exercise.

C. Taylor[30] determined the circulatory, respiratory, and metabolic responses of four male subjects (three physical education students with athletic experience and one completely untrained) to a periodically increasing work-load on a bicycle ergometer set at 70 rpm. All experiments were continued without interruption until the subject was forced to quit from exhaustion.

On the approach to maximal levels there was no manifest sign of circulatory failure accompanying exhaustion; however, failure of an adequate blood supply to certain

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[30]Craig Taylor, "Studies in Exercise Physiology," American Journal of Physiology, 135:27-42, December 1941-February, 1942.

tissues was thought to possibly affect the onset of exhaustion.

Total ventilation displayed a linear increase with work-load tending toward excessive acceleration at maximal levels. The rate of increase varied considerably between subjects but was fairly constant for each individual. Final ventilations ranged from 40 to 115 liters per minute.

The rate of oxygen consumption was considered to be a highly significant physiological variable not only because it represented the physiological cost of the work, but because it gave evidence of the transport capacity of the circulatory and respiratory mechanisms. The oxygen consumption curve as related to work load was found to be a good measure of the efficiency of the subject. The trend of oxygen consumption at maximal levels was considered to be of great significance because of the prevailing view that the ability to absorb oxygen is a limiting factor in an individual's physical performance. In Taylor's study oxygen consumption was by no means always deficient at exhaustion levels. In fact, in 50 per cent of the cases no deviation in the linear increase of oxygen intake occurred and in the remaining cases the value accelerated rather than declined. In the cases where the curve turned upward approaching exhaustion it was the opinion of the author that the effectiveness of the muscles performing the work had to lower to necessitate the mobilization of additional motor units to be able to sustain the rate of work.

The alveolar pCO_2 and per cent CO_2 in expired air both increased in the transition from rest to work and remained on a fluctuating plateau throughout most of the work range and declined sharply at exhaustion. These variables as well as ventilation were considered to be the most reliable signals of exhaustion onset.

Wyndham and associates[31] tested four highly trained men at various levels of work on the bicycle ergometer to attempt to determine the level at which maximal oxygen intake is attained and to compare the results with previous studies. The subjects warmed up for ten minutes at 3000 ft. lb/min. followed by a training run on the cycle set at 70 rpm at 7500 ft. lb/min. for thirty minutes each day. After the training run they worked to exhaustion at various levels of work between 9000 and 11,000 ft. lb/min. Training covered a period of four months.

The maximal oxygen level remained constant over a number of months. The average coefficient of variation of heart rate of the four men at the same three levels of work was 3.5 per cent indicating that in trained men maximal heart rate is constant.

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[31] C. H. Wyndham, N. B. Strydom, J. S. Maritz, J. F. Morrison, J. Peter, and Z. U. Potgieter, "Maximum Oxygen Intake and Maximum Heart Rate During Strenuous Work," Journal of Applied Physiology, 14:927-936, 1959.

There was a significant difference between the maximal observed heart rate of some of the men. The mean of the asymptote values was 178.3 beats per minute as compared to Astrand's[32] mean heart rate for young men which was 194.6 beats per minute.

The authors found that after the maximal heart rate, and presumed maximal cardiac output was reached, that the oxygen uptake continued to rise. The same investigators considered this evidence that a small additional quantity of oxygen could be obtained from the circulating minute-volume of blood after the maximal cardiac output was attained.

The authors discussed criterion used by other authors in the determination of an absolute level of maximal oxygen uptake attainment and rejected them due to their own study results and conclusions. Wyndham and associates felt that there was not sufficient knowledge of the relationships between oxygen uptake and rate of work to accept with certainty criteria for determining maximal oxygen intake attainment.

Schneider[33] tested 6 sedentary men on a bicycle ergometer carrying loads of 2000, 4000, 6000, 8000, and

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[32] P. Astrand, Experimental Studies of Physical Working Capacity in Relation to Sex and Age (Copenhagen: Munksgaard, 1952).

[33] E. C. Schneider, "A Study of Responses to Work on a Bicycle Ergometer," American Journal of Physiology, 97:353-364, April to July, 1931.

10,000 foot pounds at a set rate of 70 rpm's/minute. Preceding the experiment and between each work period of six to eight minutes the subject completely rested for twenty minutes.

A linear relationship between oxygen consumption and work load was maintained during submaximal work; however, as work load increased the linear relationship was broken for four out of the six cases. Heart rate also maintained an approximate linear relationship to work load; however, it was found to vary from man to man. Beyond this oxygen uptake and heart rate responded to the load to a lesser degree than at submaximal loads. An overload was found to fail to increase oxygen uptake. Schneider considered this to be sufficient evidence to conclude that a load of work may be undertaken in which heart rate will also be unable to increase.

Oxygen pulse rose steadily with an increase in work load except for the heaviest loads. Some of the subjects made only a slight addition to the oxygen pulse upon reaching their maximum load but a few were able to increase beyond expectation even at the heaviest loads.

Mitchell, Sproule, and Chapman[34] administered a treadmill test to determine the physiological meaning of the

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[34] J. H. Mitchell, B. J. Sproule, and C. B. Chapman, "The Physiological Meaning of the Maximal Oxygen Intake Test," Journal of Clinical Investigation, 37:538-547, 1958.

maximal oxygen intake to 65 normal men. Subjects warmed up for ten minutes at 3 mph on a 10 per cent grade which was followed by a ten minute rest period. After the rest the subject ran at 6 mph at zero grade for 2-1/2 minutes. After another ten minute rest period the grade was raised 2-1/2 per cent (speed remaining at 6 mph) and the procedure was repeated. This procedure continued until oxygen intake per minute leveled off.

Maximal intake was taken at the point at which the oxygen intake curve ceased to rise. In 72 per cent of the cases oxygen intake either remained the same or declined when work load was increased beyond this intake. Because of a relatively slight rise in some cases a final value of 54 ml or a rise of less than 142 minus 88 ml per minute was accepted as the criterion to determine at which point maximal oxygen intake was attained. The mean maximal oxygen intake was 3.22 liters ± 0.46 per minute and the mean maximal heart rate was 187 ± 10 per minute.

Robinson[35] administered a treadmill test to 93 normal non-athletic males ranging in age from 6 to 91 years to study the interrelations of age, basal heart rate, and the adaptation of heart rate work to various levels of work. The subjects walked for fifteen minutes at 5.6 mph on an

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[35] Sid Robinson, "Experimental Studies of Physical Fitness in Relation to Age," Arbeitsphysiologie, 10:251-323, 1938.

8.6 per cent grade. After a ten minute rest they ran at a rate which exhausted them in two to five minutes.

Men aged 20 to 29 attained an average maximal heart rate of 189 beats per minute as compared to a mean of 195[36] and ranges of 174 to 192 (men) and 168 to 192 (women)[37] of comparable studies. The mean maximal oxygen consumption of subjects 18 years of age was 3.61 liters per minute and of subjects 25 years of age 3.56 liters per minute.

Studies Concerning Maximal Work Capacity as Related to Physical Activity

Knehr, Dill, and Neufield[38] performed a study on 14 college men over a period of six months. Data were collected before and during the training period for subjects working to maximum on the motor driven treadmill. The subjects walked for eight minutes at 3.5 mph on an 8.6 per cent grade and then immediately ran on the same grade, or a higher grade, at 7 mph for five minutes or until exhausted.

The same investigators found a mean increase of 60 per cent in work done due to greater use of anaerobic mecha nisms for energy transformation as evidenced by an increased

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[36] D. B. Dill and L. Brouha, *Travail Humain*, 5:1, 1937.

[37] E. H. Christensen, *Arbeitsphgsiologie*, 4:453, 1931.

[38] C. A. Kneur, D. B. Dill, and W. Neufield, "Training and Its Effects on Man at Rest and at Work," *American Journal of Physiology*, 136:148-155, March-July, 1942.

maximal oxygen intake. This was indicated by increased lactate tolerance and an increased oxygen debt. The authors concluded that the capacity to accumulate lactate runs parallel with and furnishes an excellent index to cardiovascular fitness. There was also an increase in oxygen transport to the working tissues which represented a gain in aerobic work capacity.

Astrand,[39] in a review of the literature, summarized the effects of training evident during maximal work. The effects of training are:

a. An unchanged maximal heart rate,

b. An increased aerobic capacity,

c. An increased oxygen debt capacity,

d. An increased capacity for supplying oxygen to the tissues,

e. An increased utilization of anaerobic reserves,

f. An increased lactic acid capacity, and

g. An increased blood sugar level.

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[39]Astrand, "Human Physical Fitness with . . . ," loc. cit.

CHAPTER III

METHODOLOGY

To determine the relationship of body composition, strength, and habitual physical activity to maximal oxygen consumption in young college women the following methods and procedures were followed.

Subjects

The 28 women used in this experiment were undergraduate students at Michigan State University between the ages of 18 and 22. The majority of the women were freshmen, 17 of which were physical education majors and 11 which were non-majors attending instructional classes in physical education. They did not represent a random sample of young women since they were selected on a volunteer basis with an attempt to select subjects representative of different levels of habitual physical activity. All subjects were examined by the university hospital and were considered to be of good health.

Test Procedures and Data Obtained

Data collection covered a period of approximately five months. Measurements on each subject were completed in two testing periods of an approximate length of one hour each. Subjects were tested five days a week beginning at 7:00 A.M. and ending at 5:00 P.M. All metabolic data were collected in the A.M. from 7:00 to 12:00 Noon.

Anthropometric Measurements

The procedures followed for these measurements were taken from the instructions issued by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council.[40]

Height. The subject removed shoes; stood with her back against the calibration on the stadiometer; heels, hips, shoulders, and head touching the backboard. The head was erect with the chin tucked in slightly. The subject stood as tall as possible. The square was placed against the calibration on the backboard above the head of the subject. It was brought down until it fitted firmly against the top of the subject's head. The reading was taken at the lower edge of the square. Height was recorded to the nearest one-half centimeter.

Weight. The subjects were weighed without shoes in standardized dress of bermudas, blouse, and socks. Weight was recorded to the nearest half-kilogram.

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[40] Committee on Nutritional Anthropometry of the Food and Nutrition Board, Nutritional Research Council, in Body Measurements and Human Nutrition, J. Brozek, editor (Detroit: Wayne University Press, 1956).

Per cent of standard weight (relative weight). Per cent standard weight was calculated by dividing the predicted weight into the actual weight. The predicted weights were obtained from the Build and Blood Pressure Study.[41]

The standard weight figures in the Build and Blood Pressure Study included shoe heel height of about two inches and usual indoor clothing, which on women approximates four to six pounds. In order to make the figures in this study comparable the average heel height of one inch was added to each height and two pounds added to the weight to cover the extra clothing.

Pubic skinfold. The pubic skinfold site is located on the mid-abdominal line halfway between the umbilicus and the pubis. The skinfold was grasped between the thumb and index finger in the vertical plane of the body. The size of the skinfold was enough to include two thicknesses of skin and subcutaneous fat but no fascia.

The application of the Lange* Calipers was about 1 cm. from the fingers and at a depth approximately equal to the thickness of the fold. Three successive measurements were

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[41]Build and Blood Pressure Study, op. cit.

*Werna-Gren Aeronautical Research Laboratory, Kentucky Research Foundation, University of Kentucky, Lexington, Kentucky.

taken on the right side of the body while the subject was in a supine position. The three measurements were averaged and recorded in mm.

Predicted specific gravity. Predicted specific gravity was obtained by the use of the prediction formulas devised by Young and her associates.[42] The pubis skinfold measurement and the per cent of standard weight were based on the predicted weight for age and height as determined by the Build and Body Structure Study.

Per cent fat of body weight. Per cent fat of body weight was derived from the Rathbun and Pace formula[43] using specific gravity figures.

Physical Activity

All subjects completed an activity history recall questionnaire in which they recorded their activity for a consecutive five day period. Energy expenditure, i.e., physical activity, was determined by computing the activity in terms of calories per hour per body weight. The subjects were listed in rank order according to the total energy expended in activity over the five day period.

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[42] Young, *et al.*, "Body Composition of Young Women," *op. cit.*, p 334.

[43] Rathbun and Pace, *op. cit.*, p. 675.

Metabolic and Heart Rate Techniques

The maximal work capacity test. Subjects began walking on the Reeves motor driven treadmill at 3.5 mph on zero grade for ten minutes. During this ten minute "warm up" period oxygen was not collected nor heart rate recorded. During the last thirty seconds of the walk the subject was connected to a Collins plastic triple "J" high velocity valve by means of a rubber mouthpiece with the nose being completely closed with a nasal clamp. At the end of the tenth minute the treadmill speed was increased to 6 mph (without interrupting the experiment) to begin the "run." At the completion of each minute of the "run" the grade was raised one per cent until the subject was unable to continue. The speed remained constant at 6 mph throughout the "run."

Subject dress. The subjects wore standardized dress of bermuda shorts, blouse, athletic socks, and tennis shoes.

Electrode placement. The chest-back type electrodes were used to record heart rate during the "run." The three sites of electrode placement were:

a. On the chest: one inch above and to the center of the left breast,

b. On the chest: one inch below and to the center of the left breast, and

c. On the back: parallel with the lower chest electrode and three inches to the left of the spinal column.

Cramer Tuf-skin was applied to the skin site and then roughed with paper toweling to insure electrode placement. A small area (the size of the electrode) was scraped clear of tuf-skin at the exact spot of the electrode placement. The inner cap of the placement side of the electrode was thinly covered with Sanborn Redux Electrode paste before placing the electrode in the cleared area of the site. Johnson and Johnson one inch waterproof adhesive tape was then placed over the electrode to stabilize it. The center of the three inch strip of tape was placed on the electrode and held in place as one side of the tape was stretched and secured to the side of the electrode and then the same procedure was repeated to secure the other side of the tape. Duke elastoplast (a four inch square) was stretched and placed over the tape and electrode to prevent the tape from loosening or curling due to body perspiration during activity. The electrode lines were then brought toward the left shoulder, straight but with slight slack, looped, and secured to the shoulder with adhesive tape. The cord extended through the collar of the blouse and was inserted into the Sanborn portable electrocardiograph recorder.

Subject directions. The subject was directed to walk and run using her natural stride and to attempt to focus on a point directly ahead of her. It was emphasized that an all out performance would be necessary for the experiment to be successful. The nose clip and mouthpiece were positioned to give her the proper feel of the equipment. (The valve was adjusted to her height by raising or lowering the valve attached by a rubber hose clamped over an overhead ceiling bar.) All subjects were able to adjust to the treadmill during the ten minute warm up walk and had no difficulty adapting to the speed change of the run.

Experiment procedures. Seven persons were necessary to administer the all out test on the treadmill. Each testor had a specific responsibility during the all out run. The jobs consisted of:

a. Operating the Reeves motor driven treadmill: to regulate the speed at 3.5 mph for the ten minute walk on zero grade and at 6 mph during the run with a one per cent grade increase each minute;

b. Operating the Sanborn portable electrocardiograph and twin visa recorder: recording heart rate and calling a 5 second count down at the end of each thirty seconds;

c. Exchanging the Douglas gas bags each thirty seconds;

d. Standing along side of, encouraging, and watching the subject for signs of impending exhaustion;

e. Transporting the Douglas gas bags to the person operating the Fisher gas partioner and the Beckman infared 02 analyzer;

f. Operating the Fisher gas partioner and the Beckman infared 02 analyzer: to analyze the expired air for carbon dioxide and oxygen content, and

g. Operating the Kofranyi meter: to determine the temperature and volume of the gas metered.

Calculated maximal work capacity data. The following data were calculated:

a. Maximal oxygen uptake in liters per minute,

b. Maximal oxygen uptake per kilogram of body weight in liters per minute,

c. Maximal oxygen uptake per kilogram of fat-free body weight in liters per minute,

d. Time (in minutes) of maximal oxygen uptake attainment,

e. Heart rate simultaneous with the maximal oxygen uptake attainment,

f. Heart rate of the last minute on the treadmill,

g. Total treadmill time (in minutes),

h. Exercise R.Q. simultaneous with maximal oxygen attainment,

i. Maximal R.Q.,

j. Oxygen pulse,

Determination of maximal oxygen attainment. The thirty second gas bags (necessary due to the smallness of the bags available) were analyzed and the readings combined to determine one minute oxygen per kilogram of body weight calculations. The criteria for determining maximal oxygen consumption was the same as used by Taylor.[44] Taylor stated that "if the oxygen intake at two different grades differs by less than 150 cc/min. or 2.1 cc/kg of body weight, it can be safely assumed that the maximal oxygen has been attained." In the present study maximal oxygen consumption did not show in the same way for all subjects. In thirteen of the cases maximal oxygen rose to a peak followed by a decline and in the remaining fifteen cases it rose upward and then leveled off. In those cases where there was a peak followed by a decline maximal oxygen was taken at the peak minute. In those cases where the oxygen consumption leveled off and was relatively constant over the previous minute maximal oxygen consumption was taken in the minute where there was no further increase over .00150 liters per minute.

Cable Tension Strength

Eleven strength measures were determined by use of the cable tensiometer. The strength measures included:

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[44]Taylor, et al., op. cit., p. 79.

a. Shoulder Extension

b. Elbow Extension

c. Ankle Extension

d. Elbow Flexion

e. Shoulder Horizontal Flexion

f. Hip Flexion

g. Hip Extension

h. Shoulder Flexion

i. Trunk Flexion

j. Trunk Extension

k. Knee Extension

The measures were taken at least twice at each site according to instructions outlined by Clarke.[45] If the second measure differed from the first by more than 2.0 points additional measures were made until two of the measures differed by not more than 2.0 kg when corrected. The first of the two measures differing by not more than 2.0 kg were averaged and recorded.

Directions and diagrams for subject positioning and cable tensiometer attachments as taken from Clarke's[46] manual of cable tension strength tests are reprinted here with permission granted by personal communication with the author.

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[45] H. Harrison Clarke, A Manual: Cable Tension Strength Tests (Chicopee: Brown-Murphy Company, 1953).

[46] Ibid.

Shoulder Extension.[47]

Starting Position

a. Subject in supine lying position; hips and knees flexed, feet resting on table; free hand resting on chest.

b. Upper arm on side tested adducted at shoulder to 180 degrees; shoulder flexed to 90 degrees; elbow flexed with wrist in prone position.

Attachments

a. Regulation strap around humerus midway between shoulder and elbow joints.

b. Pulling assembly attached to wall at subject's head.

Precautions

a. Prevent shoulder elevation by bracing with hand.

b. Prevent humerus abduction by guiding elbow.

Objectivity coefficients: 0.97

Figure 1. Shoulder Extension

[47]Ibid., pp. 17-18.

Elbow Extension.[48]

Starting Position

a. Same as for Elbow Flexion, except elbow is in 40 degrees flexion.

Attachments

a. Regulation strap around forearm midway between wrist and elbow joints.

b. Pulling assembly hooked to wall below subject's head.

Precautions

a. Prevent shoulder elevation by bracing.

b. Prevent raising elbow and abudcting upper arm by bracing elbow to side.

c. Require subject to keep head straight so as to reduce tendency to flex the spine laterally.

Objectivity coefficient: 0.94

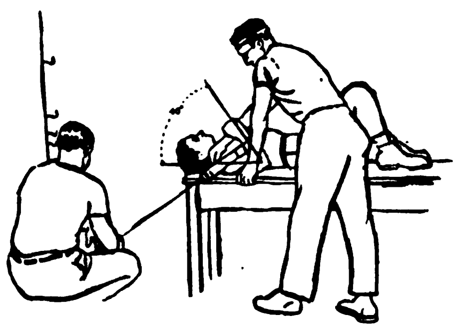

Figure 2. Elbow Extension

[48] *Ibid.*, pp. 16 and 18.

Ankle Plantar Flexion.[49]

Starting Position

a. Subject in supine position; hips in 180 degrees extension and adduction; knees in 180 degrees extensions; arms folded on chest.

b. Ankle on side tested is in 90 degrees plantar flexion.

Attachments

a. Regulation strap around food above metatarsal-phalangeal joint.

b. Pulling assembly attached to wall at subject's head.

Precautions

a. Prevent: inversion or eversion at ankle joint, extension of metatarsal-phalangeal joint; and raising of leg.

b. Brace behind shoulders to stabalize subject.

Objectivity coefficient: 0.93

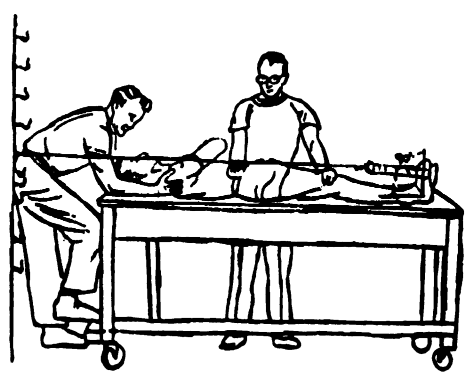

Figure 3. Ankle Plantar Flexion

[49]*Ibid.*, pp. 30-31.

Elbow Flexion.[50]

Starting Position

a. Subject in supine lying position, hips and knees flexed, feet resting on table, free hand resting on chest.

b. Upper arm on side tested adducted and extended at shoulder to 180 degrees; elbow in 115 degrees flexion; forearm in mid-prone supine position.

Attachments

a. Regulation strap around forearm mid-way between wrist and elbow joints.

b. Pulling assembly hooked at wall at subject's feet.

Precautions

a. Prevent raising elbow and abducting upper arm by bracing at elbow.

Objectivity coefficient: 0.95

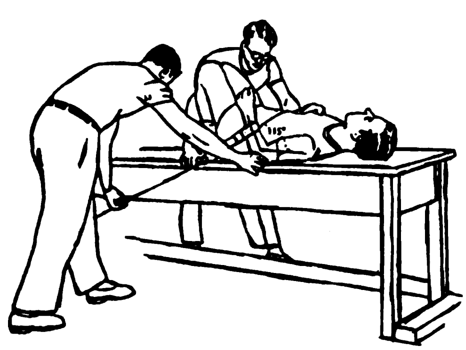

Figure 4. Elbow Flexion

[50]Ibid., pp. 16 and 18.

Shoulder Horizontal Flexion.[51]

Starting Position

a. Subject in supine lying position; hips in 180 degrees extension and adduction; knees fully extended; free hand on chest.

b. Upper arm on side tested flexed at shoulder to 90 degrees; elbow flexed to 90 degrees; forearm directly across body in mid-prone-supine position.

Attachments

a. Regulation strap around humerus midway between shoulder and elbow joints.

b. Pulling assembly attached to wall away from body.

Precautions

a. Prevent trunk from lateral flexion and shoulders from lifting by bracing; require subject to keep head straight.

b. Steady subject's arm in testing position by holding.

Objectivity coefficient: 0.93

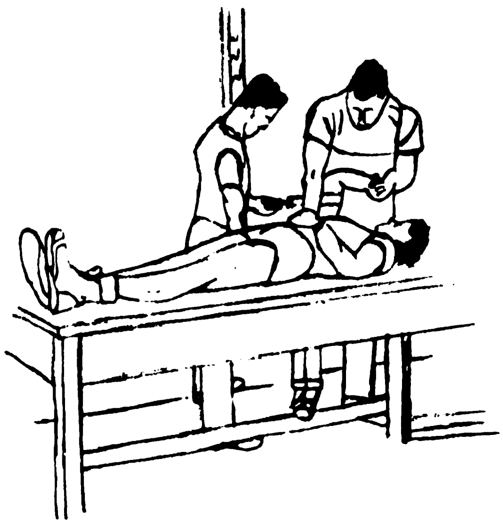

Figure 5. Shoulder Horizontal Flexion

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[51] Ibid., pp. 17-19.

Hip Flexion.[52]

Starting Position

a. Subject in supine lying position; hip and knee of free leg flexed with foot resting on table; arms folded on chest.

b. Hip and knee of leg being tested extended and adducted to 180 degrees.

Attachments

a. Regulation strap around thigh, lower third between hip and knee joints.

b. Pulling assembly attached beneath subject through slit in table.

Precautions

a. Prevent lifting of shoulders by bracing.

Objectivity coefficient: 0.90

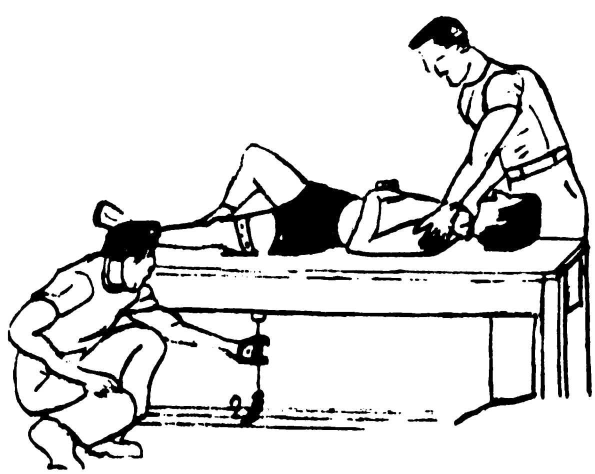

Figure 6. Hip Flexion

[52] Ibid., pp. 24-25.

Hip Extension.[53]

Starting Position

a. Subject in prone lying position; hip in 180 degrees extension and adduction; knees fully extended; arms along sides of body.

Attachments

a. Regulation strap around thigh, lower third between hip and knee joints.

b. Pulling assembly attached beneath subject through slit in table.

Precautions

a. Prevent lifting of hips by bracing.

Objectivity coefficient: 0.94

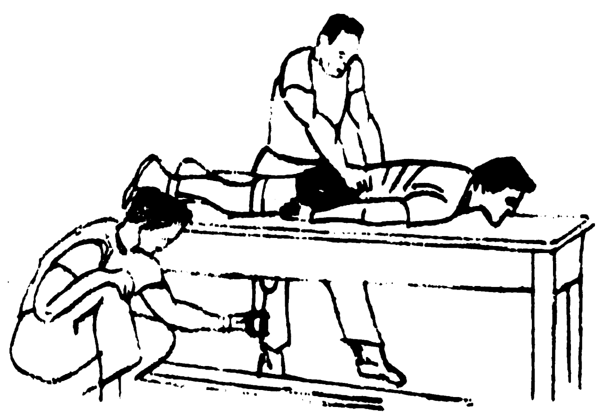

Figure 7. Hip Extension

[53] Ibid., pp. 25-26.

Shoulder Flexion.[54]

Starting Position

a. Subject in supine lying position, hips and knees flexed, feet resting on table; free hand resting on chest.

b. Upper arm on side tested adducted at shoulder to 180 degrees; shoulder flexed to 180 degrees; elbow in 90 degrees flexion.

Attachments

a. Regulation strap around humerus mid-way between shoulder and elbow joints.

b. Pulling assembly hooked to cross piece below subject's arm.

Precautions

a. Prevent shoulder elevation by bracing with hand.

b. Maintain right angle at elbow.

Objectivity coefficient: 0.94

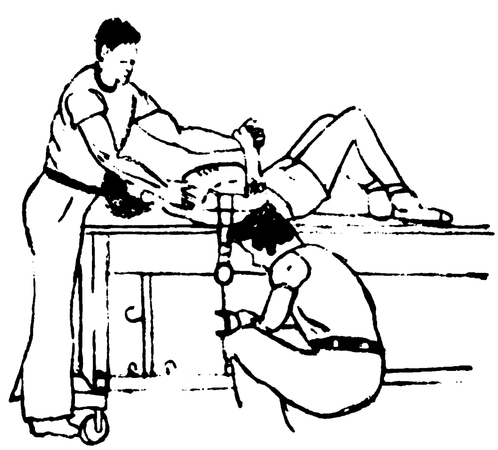

Figure 8. Shoulder Flexion

[54]Ibid., pp. 16-18.

Trunk Flexion.[55]

Starting Position

a. Subject in supine lying position; hips in 180 degrees extension and adduction; knees fully extended; arms folded on chest.

Attachments

a. Trunk strap around chest, close under arm pits.

b. Pulling assembly attached beneath subject through slit in table.

Precautions

a. Prevent lifting of hips by bracing.

Objectivity coefficient: 0.90

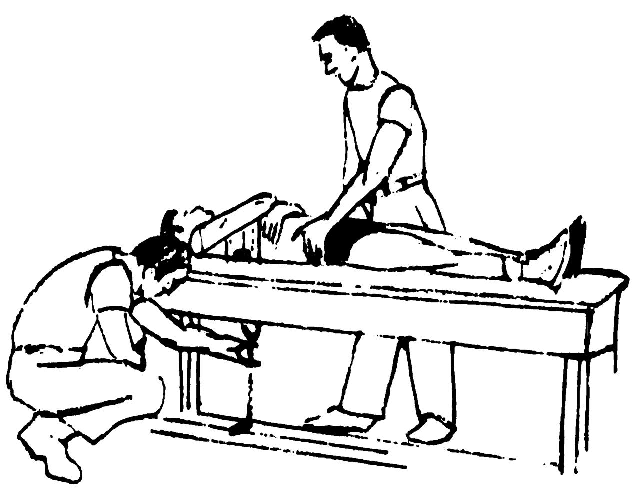

Figure 9. Trunk Flexion

[55] Ibid., pp. 23 and 25.

Trunk Extension.[56]

This test is performed in the same manner as trunk Flexion, except subject is in prone position with hands clasped behind back.

Objectivity coefficient: 0.99

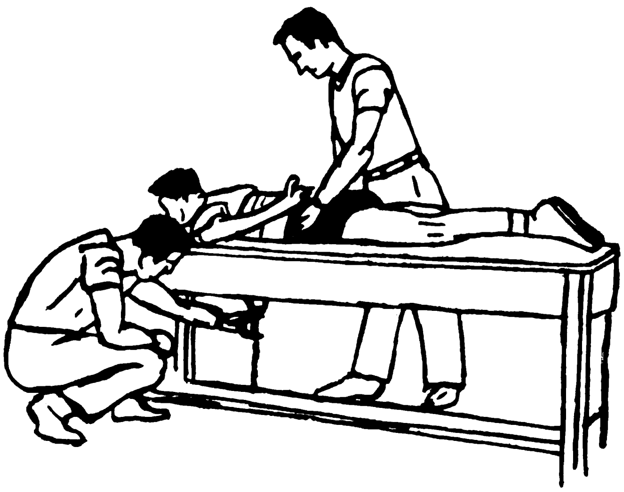

Figure 10. Trunk Extension

[56] Ibid., pp. 23 and 25.

Knee Extension.[57]

Starting Position

a. Subject in sitting, backward-leaning position; arms extended to rear, hands grasping sides of table.

b. Knee on side tested in 115 degrees extension.

Attachments

a. Regulation strap around leg midway between knee and ankle joints.

b. Pulling assembly attached to hook at lower end of table.

Precautions

a. Prevent lifting buttocks.

b. Prevent flexion of arms.

Objectivity coefficient: 0.94

Figure 11. Knee Extension

[57]Ibid., pp. 28 and 31.

CHAPTER IV

ANALYSIS OF DATA

Description of Subjects and Comparative Data

A general description of the subjects is presented in Table IV. Comparative data of the present study and Young's[58] study on body composition and specific gravity are also shown in Table IV. The mean values in Young's study for body weight (58.96 kg) and fat-free body weight (42.15 kg) are almost identical to that of the present study; 58.46 kg and 43.89 kg respectively. The other measures are also similar.

Maximal work capacity. Maximal oxygen consumption was determined on 28 young women who ran on the treadmill at 6 mph with a one per cent grade increase each minute until unable to continue. The "run" was preceded by a ten minute warm-up "walk" at 3.5 mph on zero grade. Eight subjects re-ran on the treadmill at maximal capacity to determine the reliability. The metabolic responses

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[58] Charlotte Young, "Body Composition of Young Women," Journal of the American Dietetic Association (April, 1961), 38:332-340.

TABLE IV

SUBJECT GENERAL DESCRIPTION, BODY COMPOSITION, AND PREDICTED SPECIFIC GRAVITY OF YOUNG'S STUDY AS COMPARED WITH THE PRESENT STUDY

Characteristics	Young's Study			Present Study		
	Mean	S.D.	Range	Mean	S.D.	Range
Body weight in kilograms	58.96	6.445	44.11 - 76.20	58.46	6.32	48.0 - 69.0
Fat-free body weight in kilograms	42.15	6.073	31.94 - 61.11	43.89	3.90	37.0 - 50.0
Per cent of body fat (Rathbun-Pace formula)	28.69	4.856	15.81 - 38.62	24.71	2.84	20.5 - 31.7
Predicted specific gravity	1.0408	.0096	1.0217 - 1.0665	1.054	.0070	1.035-1.057
Per cent of standard weight	98.93	8.61	83.2 - 128.0	102.95	8.66	84.65-128.39
Age in years and months	20.36	1.951	17.2 - 27.2	18.2	1.2	18.0 - 22.9
Standing height in centimeters	167.47	6.10	140.8 -181.1	164.28	5.89	150.0 -175.5
Ponderal index				12.82	.5507	11.66-13.94

to the maximal test and retest are presented in Table V. The reliability correlations are also shown in Table V.

Mean metabolic responses to maximal work capacity as compared to the mean results of other studies on women by I. Astrand,[59] P. O. Astrand,[60] Metheny,[61] and Von Dobeln[62] are presented in Table VI.

It is interesting to note the work of others as compared to the present study. Maximal work capacity as correlated with different body composition measures compared similarly with four other studies even though the subjects used in the other studies were men. Table VII presents maximal oxygen consumption as correlated with body composition measures of the present study and those of Buskirk and Taylor,[63] Von Dobeln,[64] Welch,[65] and Seltzer.[66]

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[59] Astrand, "Aerobic Work Capacity . . ., " loc. cit.

[60] Ibid.

[61] Metheny, et al., loc. cit.

[62] Von Dobeln, "Human Standard and Maximal Metabolic Rate . . .," loc. cit.

[63] Buskirk and Taylor, loc. cit.

[64] Von Dobeln, "Maximal Oxygen Intake, Body . . .," loc. cit.

[65] Welch, et al., loc. cit.

[66] Seltzer, loc. cit.

TABLE V

METABOLIC RESPONSES TO MAXIMAL WORK CAPACITY OF TEST ONE AS COMPARED TO THE RETEST

Characteristics	Test 1 N = 28			Retest N = 8			Retest
	Mean	S.D.	Range	Mean	S.D.	Range	r
Maximal oxygen consumption in liters per minute	2.19	.3628	1.65 - 3.12	2.21	.2913	1.81 - 2.67	.91
Maximal oxygen consumption per kilogram of body weight in liters per min.	.0369	.0038	.0289 - .0440	.0380	.0029	.0345- .0423	.78
Maximal oxygen consumption per kilogram of fat-free body weight in liters/min.	.0499	.0062	.0397 - .0637	.0510	.0043	.0457- .0575	.79
Time of maximal oxygen attainment in minutes	14:45	1:29	13:00 - 18:00	15:45	1:48	13:00- 18:00	.73
Heart rate simultaneous with maximal oxygen attainment	189	9.71	174 - 215	194	10.58	183- 216	.47
Total treatmill time in minutes	15:00	1:29	13:00 - 18:00	15:47	1:36	14:00- 18:30	.82
Last minute on treadmill heart rate	194	8.15	174 - 215				
R.Q.simultaneous with maximal oxygen attainment	1.05	.113	.91 - 1.37				
Maximal R. Q.	1.14	.192	.93 - 1.74				
Oxygen pulse	11.6	2.23	9.3 - 15.4				

TABLE VI

MEAN METABOLIC RESPONSES TO MAXIMAL WORK OF THE PRESENT STUDY AS COMPARED TO OTHER STUDIES ON WOMEN

Characteristics	I. Astrand[a]	P.O. Astrand[b]	P.O. Astrand[c]	Metheny[d]	Von Dobeln[e]	Present Study
Maximal oxygen consumption in liters per minute	2.23	2.90	2.88		3.06	2.19
Maximal oxygen consumption per kilogram of body weight per minute	39.9 ml	48.4 ml	48.4 ml.	40.9 cc.		36.9ml
Maximal heart rate	187	198	199	197		189
Oxygen pulse	11.9					11.6
Maximal R. Q.				1.06		1.05

[a] Irma Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, Vol. 49, Supplementum 169:11-87, 1960.

[b] P. O. Astrand, "Human Physical Fitness with Special Reference to Sex and Age," Physiological Review, 36:307-335, July, 1956.

[c] P. O. Astrand and I. Rbyming, "A Nonogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7:218-221, July, 1954.

[d] E. Metheny, et al., "Some Physiologic Responses of Men and Women to Moderate and Strenuous Exercise: A Comparative Study," American Journal of Physiology, 137:318-326, August-November, 1942.

[e] W. Von Dobeln, "Human Standard and Maximal Metabolic Rate in Relation to Fat-Free Body Mass," Acta Physiologica Scandinavica, Vol. 37, Supplementum 126:3-38, 1956.

TABLE VII

MAXIMAL WORK CAPACITY AS CORRELATED WITH BODY COMPOSITION OF THE PRESENT STUDY AS COMPARED WITH OTHER STUDIES

Maximal Oxygen Consumption vs.	Seltzer[a]	Von Dobeln[b]	Buskirk & Taylor[c]	Welch[d]	Present Study
Body weight in kilograms	.88	---	.63	.59	.64
Fat-free body weight in kilograms	---	.76	.85	.65	.64
Per cent of body fat	---	---	---	---	.35
Standing height	.59	---	---	---	.35

[a] C. C. Seltzer, "Body Build and Oxygen Metabolism at Rest and During Exercise," American Journal of Physiology, 129:1-13, 1940.

[b] W. Von Dobeln,"Maximal Oxygen Intake, Body Size and Total Hemoglobin in Normal Man," Acta Physiologica Scandinavica, 38:193-199, September, 1956.

[c] E. Buskirk and H. Taylor, "Relationships Between Maximal Oxygen Intake and Components of Body Composition," Federation Proceedings, 13:21, March-December, 1954.

[d] B. E. Welch, et al., "Relationship of Maximal Oxygen Consumption to Various Components of Body Composition," Journal of Applied Physiology, 12:395-398, May, 1958.

Strength. Eleven cable tension strength measurements were taken in various areas of the body as outlined by Clarke[67] in A Manuel: Cable Tension Strength Tests. The means, standard deviations, and ranges found in the present study are presented in Table VIII. No comparable data on women were found in the literature.

TABLE VIII

CABLE TENSION STRENGTH IN KILOGRAMS

Characteristics	Mean	S.D.	Range
Total strength	383.96	77.00	243 - 572
Hip flexion	57/14	14.55	36.00-94.32
Hip extension	44.09	10.35	26.35-65.50
Knee extension	64.90	18.83	39.25-117.61
Shoulder extension	25.31	6.35	13.00-38.38
Elbow extension	17.08	4.25	9.75-26.88
Ankle extension	41.78	13.29	22.00-74.42
Elbow flexion	26.34	4.73	14.75-35.75
Shoulder horizontal flexion	16.90	3.92	10.75-24.65
Shoulder flexion	27.64	7.00	15.25-43.38
Trunk flexion	3-.03	10.72	14.13-60.00
Trunk extension	32.34	12.10	14.75-52.88

Interrelationships of Parameters

Pearson Product-Moment correlations. The Pearson Product-Moment Coefficient of Correlation was employed to estimate the interrelationships of parameters. Table IX presents the matrix of intercorrelations of all the variables.

[67]Clarke, op. cit.

TABLE IX

INTER-CORRELATION MATRIX OF ALL VARIABLES

	1 Maximal Oxygen Consumption in Liter per Min.	2 Maximal Oxygen Consumption in Kilograms of Body Wt. in Liters/Min.	3 Maximal Oxygen Consumption in Fat-Free Kilograms of Body Wt. in Liters/Minute	4 Time on Treadmill of Maximal Oxygen Attainment in Minutes	5 Heart Rate Simultaneous with Maximal Oxygen Attainment	6 Heart Rate during Last Minute on the Treadmill	7 Total Time on the Treadmill in Minutes	8 Per Cent of Body Fat	9 One Day Average of Caloric Expenditure	10 Body Weight in Kilograms	11 Fat-Free Body Weight in Kilograms	12 Standing Height in Centimeters	13 Ponderal Index
1	1.0000	.7572	[illegible]	[illegible]	.0794	.2402	.3488	.3473	.5947	.6439	.6387	.3547	-.2335
2		1.0000	[illegible]	[illegible]	.1399	.3171	.5547	-.1070	.2487	.0447	.1085	.2522	.1825
3			1.0000	.5391	.0730	.1360	.6215	.2372	.2760	.1799	.1291	.1231	-.0380
4				1.0000	[illegible]	-.0942	.8937	.0197	-.0201	-.2363	-.2804	.0414	.2331
5					1.0000	.6752	-.1730	-.0525	.0195	-.0077	.0365	.1177	.1016
6						1.0000	-.0627	-.0508	.1341	.1115	.1761	.1902	.0611
7							1.0000	.0279	.0154	-.1953	-.2516	.0529	.2024
8								1.0000	.1904	.6441	.3376	-.4255	-.8275
9									1.0000	.6229	.6890	.3921	-.2464
10										1.0000	.9334	.2194	-.6275
11											1.0000	.4603	-.3926
12												1.0000	.5892
13													1.0000
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													

	14 Total Strength	15 Hip Flexion Strength	16 Hip Extension Strength	17 Knee Extension Strength	18 Shoulder Extension Strength	19 Elbow Extension Strength	20 Ankle Extension Strength	21 Elbow Flexion Strength	22 Shoulder Horizontal Flexion Strength	23 Shoulder Flexion Strength	24 Trunk Flexion Strength	25 Trunk Extension Strength
1	.4390	.5078	.3172	.4977	.1735	.1890	.1191	.2984	.2989	.3312	.0023	.2547
2	.1527	.2586	.1878	.2021	.0262	-.0937	-.0782	.0470	.1276	.1462	-.1385	.0653
3	.2795	.4430	.2066	.2922	.1107	-.0365	.0410	.1339	.2457	.1899	.0149	.0409
4	.0797	.2906	.0592	-.0509	.1797	-.1784	-.0682	.0712	.1958	.1496	-.0886	.0304
5	-.1406	-.0453	.0017	-.1692	.0396	-.0079	-.2449	-.2018	.0937	-.0571	-.4376	.3310
6	-.1667	-.1098	-.0859	.0167	-.2550	-.1252	-.3440	-.1152	-.1359	-.1665	-.3736	.2522
7	.1739	.3952	.0523	.1322	.1355	-.1941	.0422	.1677	.2176	.2387	.0364	-.1391
8	.3278	.3357	-.0094	.3762	.2155	.3647	.3211	.4002	.3288	.1251	.1389	-.0227
9	.3969	.3598	.2446	.4207	.1997	.2733	.0820	.1983	.1982	.3083	.1113	.5932
10	.4507	.3633	.2450	.5685	.1777	.4460	.2570	.4413	.2813	.3179	.0735	.2967
11	.3753	.2695	.2750	.4860	.1110	.3654	.1198	.3352	.1692	.2937	-.0217	.3896
12	.1189	.0895	.3183	.1654	-.1391	-.1238	-.1369	-.1137	-.0283	.0743	-.0512	.3724
13	-.2995	-.2134	.0243	-.3241	-.2846	-.5076	-.3133	-.4542	-.3326	-.2391	-.0996	-.0119
14	1.0000	.8536	.6876	.8410	.7440	.6799	.7888	.8294	.7371	.6916	.3355	.2974
15		1.0000	.6331	.7181	.6912	.4854	.6192	.7010	.6458	.5712	.2203	.2776
16			1.0000	.6147	.3637	.2839	.3571	.5788	.4713	.5333	.0606	.3049
17				1.0000	.3858	.4284	.6210	.7549	.4934	.4977	.1924	.1608
18					1.0000	.7316	.6871	.6643	.7587	.5738	.1969	.1994
19						1.0000	.6602	.7100	.7942	.5711	.0361	.2787
20							1.0000	.6622	.6671	.4856	.3786	-.1005
21								1.0000	.7128	.6690	.0259	.0787
22									1.0000	.6870	-.0062	.1290
23										1.0000	.1254	.2557
24											1.0000	-.1084
25												1.0000

The results of the intercorrelations reveal that:

1. The two body composition measures indicating the highest relationship with maximal oxygen consumption were body weight (r = .64) and fat-free body weight (r = .64).
2. Body weight and fat-free body weight indicated a higher relationship with daily caloric expenditure than other body composition parameters. The correlations were r = .69 and r = .62 respectively.
3. Maximal oxygen consumption and trunk extension strength indicated a higher relationship with daily caloric expenditure than other metabolic and strength parameters. Maximal oxygen consumption and trunk extension strength each correlated with daily caloric expenditure r = .59.
4. The two strength measurements indicating the highest relationship with maximal oxygen consumption were hip flexion (r = .51) and knee extension (r = .50).
5. The best indicators of total strength were hip flexion (r = .88), knee extension (r = .84), and elbow flexion (r = .83).

Elementary linkage analysis. Elementary Linkage Analysis for isolating Orthogonal and Oblique Types and Typal Revelancies[68] was performed on the intercorrelation matrix

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[68]Louis L. McQuitty, "Elementary Linkage Analysis for Isolating Orthogonal and Oblique Types and Typal Relevancies," Journal of Educational and Psychological Measurement, Vol. 17, no. 2, Summer, 1957.

for the purpose of clustering related parameters. Elementary linkage is defined as "the largest index of association which a variable has with any or all of the other variables."[69] Every variable is assigned to a type or cluster in terms of its highest index of association. Each variable in a type has a higher correlation with some other variable in that type than it has with any variable not in the type. A prototype is the characteristic common to all members of the cluster. The results of the Elementary Linkage Analysis are presented in Figures 12 to 16.

The results of the Elementary Linkage Analysis of Types III to V indicated inherent relationships; i.e., strength with strength and metabolic responses with metabolic responses. Types I and II, however, indicated interrelationships of parameters of separate origins. Type I indicated that the subjects who possessed more body fat and a greater fat-free body weight were more active and were stronger in trunk extension strength. It is interesting to note that trunk extension strength did not relate to any of the other strength measures. Type II indicated that the subjects who possessed a greater fat-free body weight were able to consume more oxygen and were able to run for a longer period of time before becoming exhausted.

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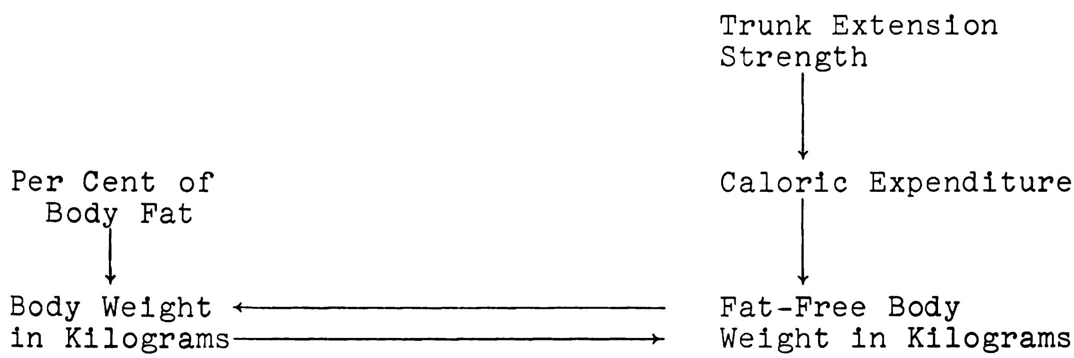
[69] Ibid., p. 208.

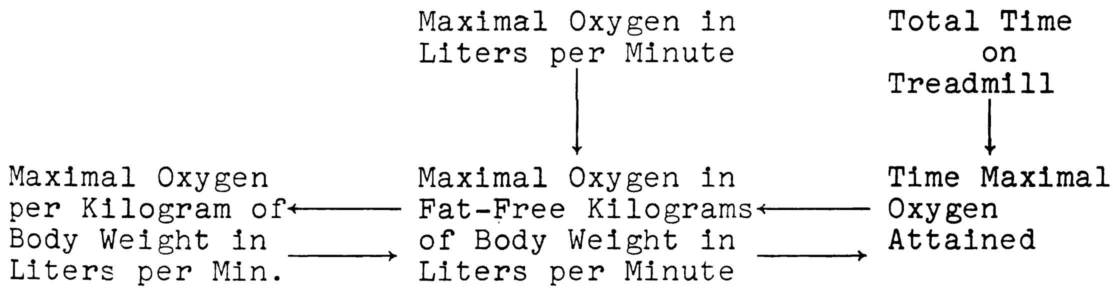


Type I

⇄ Means a reciprocal pair of variables.

→ Means that the variable at the tail of the arrow is highest with the one at the head, but the one at the head is not highest with the one at the tail.

Figure 12. Elementary Linkage Analysis: Type I

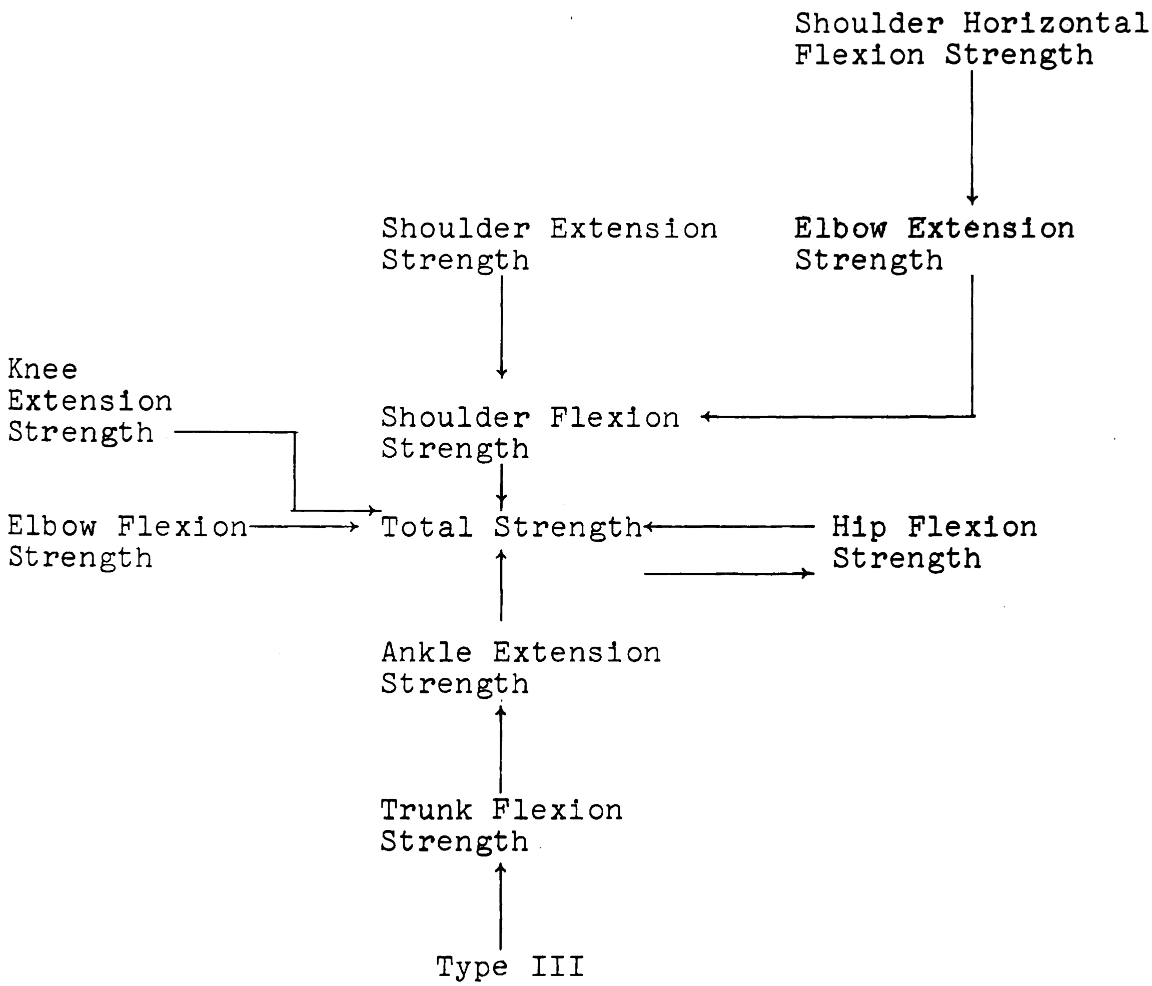


Type II

⇄ Means a reciprocal pair of variables.

→ Means that the variable at the tail of the arrow is highest with the one at the head, but the one at the head is not highest with the one at the tail.

Figure 13. Elementary Linkage Analysis: Type II



⇄ Means a reciprocal pair of variables.

→ Means that the variable at the tail of the arrow is highest with the one at the head, but the one at the head is not highest with the one at the tail.

Figure 14. Elementary Linkage Analysis: Type III

Heart Rate Simultaneous with Maximal Oxygen Attainment ⇄ Heart Rate During Last Minute on Treadmill

Type IV

⇄ Means a reciprocal pair of variables.

→ Means that the variable at the tail of the arrow is highest with the one at the head, but the one at the head is not highest with the one at the tail.

Figure 15. Elementary Linkage Analysis: Type IV

Standing Height ⇄ Ponderal Index

Type V

⇄ Means a reciprocal pair of variables.

→ Means that the variable at the tail of the arrow is highest with the one at the head, but the one at the head is not highest with the one at the tail.

Figure 16. Elementary Linkage Analysis: Type V

Analysis of Variance

One way analysis of variance using unequal subclasses was applied to determine if there were significant differences between the sub-groups. All subjects completed an activity history recall questionnaire in which they recorded their activity for a consecutive five day period. The subjects were listed in rank order according to the average daily energy expended in activity over the five day period. Next subjects were classified into two groups with two corresponding sub-groups based on rank order energy expenditure. The groups were:

Group I: The upper 20 per cent or "active" subjects as compared to the lower 20 per cent or "less active" subjects determined by a one day average of caloric expenditure, and

Group II: The upper 10 per cent or "most active" subjects as compared to the lower 10 per cent or "least active" subjects determined by a one day average of caloric expenditure.

Data on daily caloric expenditure is shown in Table X. The subjects were further classified into another group with two corresponding sub-groups. The group was:

Group III: Physical education majors as compared to non-physical education majors.

The null hypothesis states that there are no significant differences between the two groups. Variance ("F" ratio) was accepted at the .05 level of confidence.

TABLE X

DAILY CALORIC EXPENTITURE OF GROUP I, GROUP II, AND TOTAL SUBJECTS

Groups	Mean	S.D.	Range
Group I			
"Active" upper 20 per cent	2551	335	2201 - 2975
"Less Active" lower 20 per cent	664	469	371 - 992
Group II			
"Most Active" upper 10 per cent	2812	144	2688 - 2975
"Least Active" lower 10 per cent	535	101	371 - 621
All subjects	1590	687	371 - 2975

Results of analysis of variance for the upper 20 per cent or "active" subjects as compared to the lower 20 per cent or "less active" subjects. Analysis of variance data of body composition are presented in Tables XI to XV. The significant differences found upon examination of these tables are:

1. The "active" subjects were heavier than the "less active" subjects. (Significant at the .01 level of confidence.)
2. The "active" subjects possessed a greater fat-free body weight than the "less active" subjects. (Significant at the .01 level of confidence.)

Analysis of variance data of physical activity are presented in Table XVI. The significant differences found upon examination of this table are:

1. The "active" subjects expended more energy per day than the "less active" subjects. (Significant at the .01 level of confidence.)

Analysis of variance data of maximal work capacity are presented in Tables XVII to XXIII. The significant differences found upon examination of these tables are:

1. The "active" subjects possessed a greater maximal oxygen consumption in liters per minute than the "less active" subjects. (Significant at the .05 level of confidence.)

Analysis of variance data of strength are presented in Tables XXIV to XXXV. The significant differences found upon examination of these tables are:

1. The "active" subjects were stronger in trunk extension strength than the "less active" subjects. (Significant at the .01 level of confidence.)

Results of analysis of variance for the upper 10 per cent or "most active" subjects as compared to the lower 10 per cent or "least active" subjects. Analysis of variance data of body composition are presented in Tables XXXVI to XL. The significant differences found upon examination of these tables are:

1. The "most active" subjects possessed more body fat than the "least active" subjects. (Significant at the .01 level of confidence.)
2. The "most active" subjects were heavier than the "least active" subjects. (Significant at the .01 level of confidence.)
3. The "most active" subjects possessed a greater fat-free body weight than the "least active" subjects. (Significant at the .01 level of confidence.)
4. The "most active" subjects had a lower ponderal index than the "least active" subjects. (Significant at the .05 level of confidence.)

Analysis of variance data of physical activity are presented in Table XLI. The significant differences found upon examination of this table are:

1. The "most active" subjects expended more energy per day than the "least active" subjects. (Significant at the .01 level of confidence.)

Analysis of variance data of maximal work capacity are presented in Tables XLII to XLVIII. The significant differences found upon examination of these tables are:

1. The "most active" subjects possessed a greater maximal oxygen consumption in liters per minute than the "least active" subjects. (Significant at the .01 level of confidence.)
2. The "most active" subjects possessed a greater maximal oxygen consumption per kilogram of fat-free body weight in liters per minute than the "least active" subjects. (Significant at the .05 level of confidence.)

Analysis of variance data of strength are presented in Tables XLIX to LX. The significant differences found upon examination of these tables are:

1. The "most active" subjects possessed a greater total strength than the "least active" subjects. (Significant at the .05 level of confidence.)
2. The "most active" subjects were stronger in hip flexion strength, hip extension strength, knee

extension strength, elbow extension strength, and shoulder flexion strength than the "least active" subjects. (Significant at the .05 level of confidence.)

3. The "most active" subjects were stronger in trunk extension strength than the "least active" subjects. (Significant at the .01 level of confidence.)

Results of analysis of variance for the physical education majors as compared to the non-physical education majors. Analysis of variance data of body composition are presented in Tables LXI to LXV. The significant differences found upon examination of these tables are:

1. The physical education majors possessed a greater fat-free body weight than the non-physical education majors. (Significant at the .05 level of confidence.)

Analysis of variance data of physical activity are presented in Table LXVI. The significant differences found upon examination of this table are:

1. The physical education majors expended more energy per day than the non-physical education majors. (Significant at the .01 level of confidence.)

Analysis of variance data of maximal work capacity are presented in Tables LXVII to LXXIII. The significant differences found upon examination of these tables are:

1. The physical education majors possessed a greater maximal oxygen consumption in liters per minute than the non-physical education majors. (Significant at the .01 level of confidence.)
2. The physical education majors possessed a greater maximal oxygen consumption per kilogram of fat-free body weight in liters per minute than the non-physical education majors. (Significant at the .05 level of confidence.)

Analysis of variance data of strength are presented in tables LXXIV to LXXXV. The significant differences found upon examination of these tables are:

1. The physical education majors possessed a greater total strength than the non-physical education majors. (Significant at the .05 level of confidence.)
2. The physical education majors were stronger in hip extension strength than the non-physical education majors. (Significant at the .05 level of confidence.)
3. The physical education majors were stronger in trunk extension strength than the non-physical education majors. (Significant at the .01 level of confidence.)

In general then it was found that:

1. The "active" subjects (upper 20 per cent), "most active" subjects (upper 10 per cent), and the physical education majors:
   a. possessed more fat-free body weight,
   b. were more active,
   c. possessed a greater oxygen consumption, and
   d. were stronger

   than the "less active" subjects (lower 20 per cent), "least active" subjects (lower 10 per cent), and the non-physical education majors respectively.
2. The physical education majors were most like the "most active" subjects (upper 10 per cent) except that the "most active" subjects displayed greater strength in more areas of the body as compared to the "least active" subjects (lower 10 per cent) than the physical education majors as compared to the non-physical education majors.

The analysis of variance data are presented in Tables XI to LXXXV.

TABLE XI

ANALYSIS OF VARIANCE OF PER CENT BODY FAT IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Active	26.0833	Between Groups	12.0000	1	12.0000	2.42833	N.S.
Less Active	24.0833	Within Groups	49.4166	10	4.9416		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 =10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XII

ANALYSIS OF VARIANCE OF BODY WEIGHT IN KILOGRAMS IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Active	65.1666	Between Groups	385.3333	1	385.3333	24.75375	.01
Less Active	53.8333	Within Groups	155.6666	10	15.5666		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in body weight in kilograms, was accepted.

TABLE XIII

ANALYSIS OF VARIANCE OF FAT-FREE BODY WEIGHT IN KILOGRAMS IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	48.3333	Between Groups	168.7500	1	168.7500	30.04451	.01
Less Active	40.8333	Within Groups	56.1666	10	5.6166		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in fat-free body weight in kilograms, was accepted.

TABLE XIV

ANALYSIS OF VARIANCE OF STANDING HEIGHT (IN CENTIMETERS) IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	167.9333	Between Groups	184.8675	1	184.8675	3.92949	N.S.
Less Active	160.0833	Within Groups	470.4616	10	47.0461		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XV

ANALYSIS OF VARIANCE OF PONDERAL INDEX IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	12.6316	Between Groups	.2408	1	.2408	.58719	N.S.
Less Active	12.9150	Within Groups	4.1014	10	.4101		

From Table F for df_1 and df_2 = 10. F at .05 = 4.96
F at .01 =10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XVI

ANALYSIS OF VARIANCE OF CALORIC EXPENDITURE
(ONE DAY AVERAGE) IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	2517.5000	Between Groups	10310094.0832	1	10310094.0832	134.31373	.01
Less Active	663.6666	Within	767612.8330	10	76761.2833		

From Table F for df_1 = 1 and df_2 = 10. F at .05 = 4.96
F at .01 = 10.04

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in caloric expenditure (one day average), was accepted.

TABLE XVII

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE IN LITERS PER MINUTE IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	2.5583	Between Groups	.9520	1	.9520	7.48332	.05
Less Active	1.9950	Within Groups	1.2722	10	.1272		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in maximal oxygen uptake in liters per minute, was accepted.

TABLE XVIII

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE PER KILOGRAM OF BODY WEIGHT IN LITERS PER MINUTE IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	.0388	Between Groups	.0000	1	.0000	.79833	N.S.
Less Active	.0367	Within Groups	.0001	10	.0000		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XIX

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE PER KILOGRAM OF FAT-FREE BODY WEIGHT IN LITERS PER MINUTE IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	.0529	Between Groups	.0000	1	.0000	1.12838	N.S.
Less Active	.0487	Within Groups	.0004	10	.0000		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XX

ANALYSIS OF VARIANCE OF TIME (IN MINUTES) OF MAXIMAL OXYGEN UPTAKE ATTAINMENT IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	15.0000	Between Groups	.0833	1	.0833	.03356	N.S.
Less Active	14.8333	Within Groups	24.8333	10	2.4833		

From Table F for $df_1 =$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXI

ANALYSIS OF VARIANCE OF THE HEART RATE SIMULTANEOUS WITH THE MAXIMAL OXYGEN UPTAKE ATTAINMENT IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	192.5000	Between Groups	8.3333	1	8.3333	.09276	N.S.
Less Active	190.8333	Within Groups	898.3333	10	89.8333		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXII

ANALYSIS OF VARIANCE OF THE HEART RATE OF THE LAST MINUTE ON THE TREADMILL IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	195.3333	Between Groups	70.0833	1	70.0833	.96423	N.S.
Less Active	190.5000	Within Groups	726.8333	10	72.6833		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXIII

ANALYSIS OF VARIANCE OF THE TOTAL TREADMILL TIME (IN MINUTES) IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	15.0833	Between Groups	.0208	1	.0208	.00739	N.S.
Less Active	15.0000	Within Groups	28.2083	10	2.8208		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXIV

ANALYSIS OF VARIANCE OF TOTAL STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	411.8333	Between Groups	10800.0000	1	10800.0000	1.36793	N.S.
Less Active	351.8333	Within Groups	78951.6666	10	7895.1666		

From Table F for $df_1 =$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXV

ANALYSIS OF VARIANCE OF HIP FLEXION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	62.9550	Between Groups	285.7727	1	285.7727	.88066	N.S.
Less Active	53.1950	Within Groups	3244.9801	10	324.4980		

From Table F for df_1 = and df_2 = 10. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXVI

ANALYSIS OF VARIANCE OF HIP EXTENSION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	48.8133	Between Groups	123.4566	1	123.4566	1.37737	N.S.
Less Active	42.3983	Within Groups	896.3240	10	89.6324		

From Table F for df_1 = and df_2 = 10. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXVII

ANALYSIS OF VARIANCE OF KNEE EXTENSION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	75.7733	Between Groups	1306.2533	1	1306.2533	4.11172	N.S.
Less Active	54.9066	Within Groups	3176.9006	10	317.6900		

From Table F for df_1 = and df_2 = 10. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXVIII

ANALYSIS OF VARIANCE OF SHOULDER EXTENSION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	25.4183	Between Groups	4.5387	1	4.5387	.07089	N.S.
Less Active	26.6483	Within Groups	640.2713	10	64.0271		

From Table F for df_1 = 1 and df_2 = 10. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXIX

ANALYSIS OF VARIANCE OF ELBOW EXTENSION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	18.3550	Between Groups	10.0833	1	10.0833	.45715	N.S.
Less Active	16.5216	Within Groups	220.5698	10	22.0569		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXX

ANALYSIS OF VARIANCE OF ELBOW FLEXION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	41.8583	Between Groups	8.9787	1	8.9787	.04022	N.S.
Less Active	43.5883	Within Groups	2232.1905	10	223.2190		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXXI

ANALYSIS OF VARIANCE OF ANKLE EXTENSION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	36.5250	Between Groups	249.3784	1	31.1723	1.70190	N.S.
Less Active	43.5883	Within Groups	54.9486	10	18.3161		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXXII

ANALYSIS OF VARIANCE OF SHOULDER HORIZONTAL FLEXION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	17.8800	Between Groups	3.2760	1	3.2760	.14700	N.S.
Less Active	16.8350	Within Groups	222.8659	10	22.2865		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXXIII

ANALYSIS OF VARIANCE OF SHOULDER FLEXION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	28.8766	Between Groups	29.6730	1	29.6730	.39355	N.S.
Less Active	25.7316	Within Groups	753.9812	10	75.3981		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXXIV

ANALYSIS OF VARIANCE OF TRUNK FLEXION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	24.0533	Between Groups	7.2385	1	7.2385	.14349	N.S.
Less Active	25.6066	Within Groups	504.4686	10	50.4468		

From Table F for $df_1 =$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XXXV

ANALYSIS OF VARIANCE OF TRUNK EXTENSION STRENGTH IN GROUP I

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Active	43.7783	Between Groups	1494.5471	1	1494.5471	57.66748	.01
Less Active	21.4583	Within Groups	259.1663	10	25.9166		

From Table F for $df_1 = 1$ and $df_2 = 10$. F at .05 = 4.96
F at .01 = 10.04

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in trunk extension strength, was accepted.

TABLE XXXVI

ANALYSIS OF VARIANCE OF PER CENT BODY FAT IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Most Active	26.8333	Between Groups	37.5000	1	37.5000	31.03448	.01
Least Active	21.8333	Within Groups	4.8333	4	1.2083		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in per cent body fat, was accepted.

TABLE XXXVII

ANALYSIS OF VARIANCE OF BODY WEIGHT IN KILOGRAMS IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Significance
Most Active	67.0000	Between Groups	400.1666	1	400.1666	64.89189	.01
Least Active	50.0000	Within Groups	24.1666	4	6.1666		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in body weight in kilograms, was accepted.

TABLE XXXVIII

ANALYSIS OF VARIANCE OF FAT-FREE BODY WEIGHT IN KILOGRAMS IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	"F" Ratio	Signifcance
Most Active	49.0000	Between Groups	130.6666	1	130.6666	49.00000	.01
Least Active	39.6666	Within Grups	10.6666	4	2.6666		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypotheses; that there was significant differences between the groups in fat-free body weight in kilograms, was accepted.

TABLE XXXIX

ANALYSIS OF VARIANCE OF STANDING HEIGHT (IN CENTIMETERS) IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	167.7666	Between Groups	14.4150	1	14.4150	1.37308	N.S.
Least Active	164.6666	Within Groups	41.9933	4	10.4983		

From Table F for df_1 = and df_2 = 4. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XL

ANALYSIS OF VARIANCE OF PONDERAL INDEX IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	12.4933	Between Groups	1.3920	1	1.3920	13.58286	.05
Least Active	13.4566	Within Groups	.4099	4	.1024		

From Table F for df_1 = 1 and df_2 = 4. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in ponderal index, was accepted.

TABLE XLI

ANALYSIS OF VARIANCE OF CALORIC EXPENDITURE (ONE DAY AVERAGE) IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	2811.6666	Between Groups	7772540.1669	1	7772540.1669	369.78053	.01
Least Active	535.3333	Within Groups	84077.3332	4	21019.3333		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in caloric expenditure (one day average), was accepted.

TABLE XLII

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE IN LITERS PER MINUTE IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"R" Ratio	Significance
Most Active	2.8970	Between Groups	1.8559	1	1.8559	39.54743	.01
Least Active	1.7846	Within Groups	.1877	4	.0469		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in maximal oxygen uptake in liters per minute, was accepted.

TABLE XLIII

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE PER KILOGRAM OF BODY WEIGHT IN LITERS PER MINUTES IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	.0421	Between Groups	.0000	1	.0000	5.00266	N.S.
Least Active	.0352	Within Groups	.0000	4	.0000		

From Table F for df_1 = and df_2 = 4. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XLIV

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE PER KILOGRAM OF FAT-FREE BODY WEIGHT IN LITERS PER MINUTE IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	.0591	Between Groups	.0003	1	.0003	11.20136	.05
Least Active	.0450	Within Groups	.0001	4	.0000		

From Table F for df_1 = 1 and df_2 = 4. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in maximal oxygen uptake per kilogram of fat-free body weight in liters per minute was accepted

TABLE XLV

ANALYSIS OF VARIANCE OF TIME (IN MINUTES) OF MAXIMAL OXYGEN UPTAKE ATTAINMENT IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	15.6666	Between Groups	2.6666	1	2.6666	.69565	N.S.
Least Active	14.3333	Within Groups	15.3333	4	3.8333		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XLVI

ANALYSIS OF VARIANCE OF THE HEART RATE SIMULTANEOUS WITH MAXIMAL OXYGEN UPTAKE ATTAINMENT IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	191.0000	Between Groups	8.1666	1	8.1666	.04434	N.S.
Least Active	193.3333	Within Groups	736.6666	4	184.1666		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XLVII

ANALYSIS OF VARIANCE OF THE HEART RATE OF THE LAST MINUTE ON THE TREADMILL IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	192.3333	Between Groups	42.6666	1	42.6666	.37537	N.S.
Least Active	187.0000	Within Groups	454.6666	4	113.6666		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE XLVIII

ANALYSIS OF VARIANCE OF THE TOTAL TREADMILL TIME (IN MINUTES) IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	16.1666	Between Groups	5.0416	1	5.0146	1.63514	N.S.
Least Active	14.3333	Within Groups	12.3333	4	3.0833		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was acceptec.

TABLE XLIX

ANALYSIS OF VARIANCE OF TOTAL STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	489.0000	Between Groups	47526.0000	1	47526.0000	10.32725	.05
Least Active	311.0000	Within Groups	18408.0000	4	4602.0000		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in total strength, was accepted.

TABLE L

ANALYSIS OF VARIANCE OF HIP FLEXION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	77.4933	Between Groups	1790.5337	1	1790.5537	7.74145	.05
Least Active	42.9433	Within Groups	925.1775	4	231.2943		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in hip flexion strength, was accepted.

TABLE LI

ANALYSIS OF VARIANCE OF HIP EXTENSION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signif-cance
Most Active	50.8333	Between Groups	285.2461	1	285.2461	8.13027	.05
Least Active	37.0433	Within Grups	140.3379	4	35.0844		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differerences between the groups in hip extension strength, was accepted.

TABLE LII

ANALYSIS OF VARIANCE OF KNEE EXTENSION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signifi-cance
Most Active	89.2000	Between Groups	3013.6968	1	3013.6968	19.33222	.05
Least Active	44.3766	Within Groups	623.5594	4	155.8898		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in knee extension strength, was accepted.

TABLE LIII

ANALYSIS OF VARIANCE OF SHOULDER EXTENSION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	31.5433	Between Groups	71.6912	1	71.6912	.96436	N.S.
Least Active	24.6300	Within Groups	297.3626	4	74.3406		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LIV

ANALYSIS OF VARIANCE OF ELBOW EXTENSION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	21.2500	Between Groups	63.3750	1	63.3750	11.39326	.05
Least Active	14.7500	Within Groups	22.2500	4	5.5625		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in elbow extension strength, was accepted.

TABLE LV

ANALYSIS OF VARIANCE OF ELBOW FLEXION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	53.1333	Between Groups	140.3600	1	140.3600	.56330	N.S.
Least Active	43.4600	Within Groups	996.6962	4	249.1740		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LVI

ANALYSIS OF VARIANCE OF ANKLE EXTENSION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	29.9166	Between Groups	117.0416	1	117.0416	5.95758	N.S.
Least Active	21.0833	Within Groups	78.5833	4	19.6458		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant, therefore, the null hypothesis was accepted.

TABLE LVII

ANALYSIS OF VARIANCE OF SHOULDER HORIZONTAL FLEXION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	21.0500	Between Groups	42.0820	1	42.0820	2.78383	N.S.
Least Active	15.7533	Within Groups	60.4662	4	15.1165		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant, therefore, the null hypothesis was accepted.

TABLE LVIII

ANALYSIS OF VARIANCE OF SHOULDER FLEXION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	37.1266	Between Groups	317.1173	1	317.1173	9.48052	.05
Least Active	22.5866	Within Groups	133.7975	4	33.4493		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in shoulder flexion strength, was accepted.

TABLE LIX

ANALYSIS OF VARIANCE OF TRUNK FLEXION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	30.9366	Between Groups	39.6808	1	39.6808	.99877	N.S.
Least Active	25.7933	Within Groups	158.9185	4	39.7296		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio was not found to be significant, therefore, the null hypothesis was accepted.

TABLE LX

ANALYSIS OF VARIANCE OF TRUNK EXTENSION STRENGTH IN GROUP II

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Most Active	45.6700	Between Groups	1007.7695	1	1007.7695	25.86020	.01
Least Active	19.7500	Within Groups	155.8796	4	38.9699		

From Table F for $df_1 = 1$ and $df_2 = 4$. F at .05 = 7.71
F at .01 = 21.20

The F ratio showed significance at the .01 level of confidence and, therefore the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in trunk extension strength, was accepted.

TABLE LXI

ANALYSIS OF VARIANCE OF PER CENT BODY FAT IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedoms	Mean Square	"F" Ratio	Significance
Majors	24.8588	Between Groups	.9955	1	.9955	.11906	N.S.
Non-majors	24.4727	Within Groups	217.4029	26	8.3616		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXII

ANALYSIS OF VARIANCE OF BODY WEIGHT IN KILOGRAMS IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedoms	Mean Square	"F" Ratio	Significance
Majors	60.3529	Between Groups	154.3546	1	154.3546	4.34045	N.S.
Non-majors	55.4642	Within Groups	924.6096	26	35.5619		

From Table F for df_1 = and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .05 level of confidence and, therefore the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in body weight in kilograms, was accepted.

TABLE LXIII

ANALYSIS OF VARIANCE OF FAT-FREE BODY WEIGHT IN KILOGRAMS IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	45.2352	Between Groups	77.9833	1	77.9833	6.09437	.05
Non-majors	41.8181	Within Groups	332.6951	26	12.7959		

From Table F for df_1 = 1 and df_2 = 26. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in fat-free body weight in kilograms, was accepted.

TABLE LXIV

ANALYSIS OF VARIANCE OF STANDING HEIGHT (IN CENTIMETERS) IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	165.8764	Between Groups	109.9941	1	109.9941	3.45331	N.S.
Non-majors	161.8181	Within Groups	828.1469	26	31.8518		

From Table F for df_1 = 1 and df_2 = 26. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXV

ANALYSIS OF VARIANCE OF PONDERAL INDEX IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	12.7570	Between Groups	.1914	1	.1914	.62244	N.S.
Non-majors	12.9263	Within Grups	7.9964	26	.3075		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXVI

ANALYSIS OF VARIANCE OF CALORIC EXPENDITURE (ONE DAY AVERAGE) IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	1896.9411	Between Groups	4081593.5296	1	4081593.5296	12.25354	.01
Non-majors	1115.1818	Within Groups	8660472.5780	26	333095.0991		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in caloric expenditure (one day average), was accepted.

TABLE LXVII

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE IN LITERS PER MINUTE IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	2.3534	Between Groups	1.1447	1	1.1447	12.35731	.01
Non-majors	1.9394	Within Grups	2.4086	26	.0926		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in maximal oxygen uptake in liters per minute, was accepted.

TABLE LXVIII

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE PER KILOGRAM OF BODY WEIGHT IN LITERS PER MINUTE IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	.0378	Between Groups	.0000	1	.0000	3.23904	N.S.
Non-majors	.0353	Within Groups	.0003	26	.0000		

From Table F for $df_1 =$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXIX

ANALYSIS OF VARIANCE OF MAXIMAL OXYGEN UPTAKE PER KILOGRAM OF FAT-FREE BODY WEIGHT IN LITERS PER MINUTE IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	.0519	Between Groups	.0001	1	.0001	5.59941	.05
Non-majors	.0466	Within Groups	.0008	26	.0000		

From Table F for df_1 = 1 and df_2 = 26. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alterante hypothesis, that there was significant differences between the groups in maximal oxygen uptake per kilogram of fat-free body weight in liters per minute, was accepted.

TABLE LXX

ANALYSIS OF VARIANCE OF TIME (IN MINUTES) OF MAXIMAL OXYGEN UPTAKE ATTAINMENT IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	14.7647	Between Groups	.0093	1	.0093	.00411	N.S.
Non-majors	14.7272	Within Groups	59.2406	26	2.2784		

From Table F for df_1 = and df_2 = 26. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXI

ANALYSIS OF VARIANCE OF THE HEART RATE SIMULTANEOUS WITH THE MAXIMAL OXYGEN UPTAKE ATTAINMENT IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	198.1764	Between Groups	46.2307	1	46.2307	.48057	N.S.
Non-majors	187.5454	Within Groups	2501.1978	26	96.1999		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXII

ANALYSIS OF VARIANCE OF THE HEART RATE OF THE LAST MINUTE ON THE TREADMILL OF GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	195.3529	Between Groups	111.1858	1	111.1858	1.71658	N.S.
Non-majors	191.2727	Within Groups	1684.0641	26	64.7716		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXIII

ANALYSIS OF VARIANCE OF THE TOTAL TREADMILL TIME (IN MINUTES) IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	15.1176	Between Groups	.0924	1	.0924	.04055	N.S.
Non-majors	15.0000	Within Groups	59.2647	26	2.2794		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXIV

ANALYSIS OF VARIANCE OF TOTAL STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	407.1176	Between Groups	23197.5632	1	23197.5632	4.40666	.05
Non-majors	348.1818	Within Groups	136869.4010	26	5264.2077		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in total strength, was accepted.

TABLE LXXV

ANALYSIS OF VARIANCE OF HIP FLEXION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	60.2029	Between Groups	714.4497	1	741.4497	3.71395	N.S.
Non-majors	49.8600	Within Grups	5001.5993	26	192.3692		

From Table F for df_1 = 1 and df_2 = 26. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXVI

ANALYSIS OF VARIANCE OF HIP EXTENSION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	47.1676	Between Groups	408.8247	1	408.8297	4.27743	.05
Non-majors	39.3436	Within Grups	2485.0359	26	95.5783		

From Table F for df_1 = and df_2 = 26. F at .05 = 4.22
F at .01 = 4.72

The F ratio showed significance at the .05 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis, that there was significant differences between the groups in hip extension strength, was accepted.

TABLE LXXVII

ANALYSIS OF VARIANCE OF KNEE EXTENSION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signifi-cance
Majors	69.6858	Between Grups	993.2195	1	993.2195	3.01098	N.S.
Non-majors	57.4909	Within Grups	8576.5007	26	329.8654		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXVIII

ANALYSIS OF VARIANCE OF SHOULDER EXTENSION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signifi-cance
Majors	26.5841	Between Groups	70.1691	1	70.1691	1.79277	N.S.
Non-majors	23.3427	Within Groups	1017.6394	26	39.1399		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXIX

ANALYSIS OF VARIANCE OF ELBOW EXTENSION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	17.7352	Between Groups	18.8052	1	18.8052	1.04441	N.S.
Non-majors	16.0572	Within Groups	468.1472	26	18.0056		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.42
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXX

ANALYSIS OF VARIANCE OF ANKLE EXTENSION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signifcance
Majors	41.0858	Between Groups	20.6347	1	20.6347	.11305	N.S.
Non-majors	42.8436	Within Grups	4745.5868	26	182.5225		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.42
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXXI

ANALYSIS OF VARIANCE OF ELBOW FLEXION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	27.3017	Between Groups	40.3844	1	40.3844	1.86341	N.S.
Non-majors	24.8427	Within Groups	563.4808	26	21.6723		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXXII

ANALYSIS OF VARIANCE OF SHOULDER HORIZONTAL FLEXION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Majors	17.7447	Between Groups	30.6417	1	30.6417	2.06889	N.S.
Non-majors	15.6027	Within Groups	385.0792	26	14.8107		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXXIII

ANALYSIS OF VARIANCE OF SHOULDER FLEXION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signif-cance
Majors	29.3758	Between Groups	130.1786	1	130.1786	2.84071	N.S.
Non-majors	24.9609	Within Groups	1191.4785	26	45.8260		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXXIV

ANALYSIS OF VARIANCE OF TRUNK FLEXION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Signifi-cance
Majors	30.2100	Between Groups	1.3964	1	1.3964	.01171	N.S.
Non-majors	29.7527	Within Groups	3100.6236	26	119.2547		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio was not found to be significant; therefore, the null hypothesis was accepted.

TABLE LXXXV

ANALYSIS OF VARIANCE OF TRUNK EXTENSION STRENGTH IN GROUP III

Group	Mean	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	"F" Ratio	Significance
Major	37.4129	Between Groups	1112.9849	1	1112.9849	10.19927	.01
Non-majors	24.5036	Within Groups	2837.2234	26	109.1239		

From Table F for $df_1 = 1$ and $df_2 = 26$. F at .05 = 4.22
F at .01 = 7.72

The F ratio showed significance at the .01 level of confidence and, therefore, the null hypothesis was rejected. The alternate hypothesis; that there was significant differences between the groups in trunk extension strength, was accepted.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was designed with the intent of determining the relationship of physical activity, strength, and body composition to the maximal work capacity of young women.

In order to realize this purpose four main objectives were selected:

1. to determine maximal oxygen capacity of young women,
2. to determine the effect of body composition on maximal oxygen consumption,
3. to determine the relationship of strength and maximal oxygen consumption, and
4. to determine the differences between active and less active individuals in relation to maximal oxygen consumption.

Data on twenty-eight college women was obtained in the following areas:

a. Body Composition: The body fat and fat-free body weight was calculated from predicted specific gravity.

b. Physical Activity: Habitual physical activity was measured by an activity history recall questionnaire.

c. Strength: Cable tension strength was assessed in eleven sites throughout the body.

d. Maximal Work Capacity: Maximal oxygen consumption was determined while performing strenuous work which consisted of running at a constant speed of 6 mph on a motor driven treadmill with a grade increase of one per cent each minute until the subject was unable to continue. The run was preceded by a ten minute warm up walk at 3.5 mph on zero grade.

Conclusions

From the statistical analysis of data the following conclusions were drawn:

Pearson Product-Moment Correlation

1. The two body composition measures indicating the highest relationship with maximal oxygen consumption were body weight (r = .64) and fat-free body weight (r = .64).
2. Body weight and fat-free body weight indicated a higher relationship with daily caloric expenditure than other body composition parameters. The correlations were r = .69 and r = .62 respectively.
3. Maximal oxygen consumption and trunk extension strength indicated a higher relationship with daily caloric expenditure than other metabolic and

strength parameters. Maximal oxygen consumption and trunk extension strength each correlated with daily caloric expenditure r = .59.

4. The two strength measurements indicating the highest relationship with maximal oxygen consumption were hip flexion (r = .51) and knee extension (r = .50).
5. The best indicators of total strength were hip flexion (r = .88), knee extension (r = .84), and elbow flexion (r = .83).

Elementary linkage analysis. The results of the Elementary Linkage Analysis indicated:

1. inherent relationships in strength and metabolic responses,
2. that the subjects who possessed more body fat and a greater fat-free body weight were more active and were stronger in trunk extension strength, and
3. that the subjects who possessed a greater fat-free body weight were able to consume more oxygen and were able to run for a longer period of time before becoming exhausted.

Analysis of Variance

One way analysis of variance using unequal subclasses was applied to determine if there were significant differences between the sub-groups. The groups as classified into sub-groups were:

Group I: the upper 20 per cent or "active subjects as compared to the lower 20 per cent or "less active" subjects determined by a one day average of caloric expenditure,

Group II: the upper 10 per cent or "most active" subjects as compared to the lower 10 per cent or "least active" subjects determined by a one day average of caloric expenditure, and

Group III: physical education majors as compared to non-physical education majors.

Results of analysis of variance for the upper 20 per cent or "active" subjects as compared to the lower 20 per cent or "less active" subjects. The significant differences were:

Body composition. The "active" subjects were heavier and possessed a greater fat-free body weight than the "less active" subjects. (Significance = .01)

Physical Activity. The "active" subjects expended more energy per day than the "less active" subjects. (Significance = .01)

Maximal Work Capacity. The "active" subjects possessed a greater maximal oxygen consumption in liters per minute than the "less active" subjects. (Significance = .05)

Strength. The "active" subjects were stronger in trunk flexion strength than the "less active" subjects. (Significance = .01)

Results of analysis of variance for the upper 10 per cent or "most active" subjects as compared to the lower 10 per cent or "least active" subjects. The significant differences were:

Body composition. The "most active" subjects possessed more body fat, were heavier, and possessed a greater fat-free body weight than the "least active" subjects. (Significance = .01)

The "most active" subjects had a lower ponderal index than the "least active" subjects. (Significance = .05)

Physical activity. The "most active" subjects expended more energy per day than the "least active" subjects. (Significance = .01)

Maximal work capacity. The "most active" subjects possessed a greater maximal oxygen consumption in liters per minute than the "least active" subjects. (Significance = .01)

The "most active" subjects possessed a greater maximal oxygen consumption per kilogram of fat-free body weight in liters per minute than the "least active" subjects. (Significance = .05)

Strength. The "most active" subjects possessed a greater total strength and were stronger in hip flexion strength, hip extension strength, knee extension strength, elbow extension strength, and shoulder flexion strength than the "least active" subjects. (Significance = .05)

The "most active" subjects were stronger in trunk extension strength than the "least active" subjects. (Significance = .01)

Results of analysis of variance for the physical education majors as compared to the non-physical education majors. The significant differences were:

Body composition. The physical education majors were heavier and possessed a greater fat-free body weight than the non-physical education majors. (Significance = .05)

Physical activity. The physical education majors expended more energy per day than the non-physical education majors. (Significance = .01)

Maximal work capacity. The physical education majors possessed a greater maximal oxygen consumption in liters per minute than the non-physical education majors. (Significance = .01)

The physical education majors possessed a greater maximal oxygen consumption per kilogram of fat-free body weight in liters per minute than the non-physical education majors. (Significance = .05)

Strength. The physical education majors possessed a greater total strength and were stronger in hip extension strength than the non-physical education majors. (Significance = .05)

The physical education majors were stronger in trunk extension strength than the non-physical education majors. (Significance = .01)

In general then it was found that:

1. The "active" subjects (upper 20 per cent), "most active" subjects (upper 10 per cent), and the physical education majors:
   a. possessed more fat-free body weight,
   b. were more active,
   c. possessed a greater oxygen consumption, and
   d. were stronger

   than the "less active" subjects (lower 20 per cent), "least active" subjects (lower 10 per cent), and the non-physical education majors respectively.
2. The physical education majors were most like the "most active" subjects (upper 10 per cent) except that the "most active" subjects displayed greater strength in more areas of the body as compared to the "least active" subjects (lower 10 per cent) than the physical education majors as compared to the non-physical education majors.

<u>Recommendations</u>

1. A valid method to assess habitual physical activity which would classify subjects into activity groups is vitally needed.
2. A larger number of randomly selected subjects are necessary to establish norms and to determine inter-relationships of body composition, metabolic, and functional characteristics of women of various ages.

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APPENDICES

APPENDIX A

RAW DATA ON PHYSICAL CHARACTERISTICS OF SUBJECTS, BODY COMPOSITION, PHYSICAL ACTIVITY, MAXIMAL WORK CAPACITY, AND STRENGTH

TABLE LXXXVI

RAW DATA ON PHYSICAL CHARACTERISTICS OF SUBJECTS

Subjects	Major*	Age in Years and Months	Height in Inches	Height in Centimeters	Weight in Pounds	Weight in Kilograms
1	P.E.	18- 5	65.50	166.5	138.7	63.0
2	P.E.	18- 4	63.78	162.5	115.5	52.5
3	P.E.	18- 6	63.08	160.3	138.6	63.0
4	P.E.	18- 8	61.22	155.5	140.3	63.8
5	P.E.	20- 0	65.06	165.5	129.8	59.0
6	P.E.	18- 0	63.68	161.8	119.6	54.4
7	P.E.	19- 2	65.35	166.0	132.6	60.3
8	P.E.	22- 9	65.35	166.0	123.8	56.3
9	P.E.	20- 0	65.80	167.3	143.8	65.4
10	P.E.	19- 4	66.83	169.8	132.1	60.0
11	P.E.	18- 6	66.93	170.0	151.1	68.8
12	P.E.	18- 8	65.17	165.5	148.2	67.4
13	P.E.	19- 4	67.81	172.3	137.4	62.5
14	P.E.	19- 0	64.96	165.0	134.1	61.0
15	N.-P.E.	18- 7	65.25	165.8	110.1	50.1
16	P.E.	18-10	63.77	162.0	124.3	56.5
17	P.E.	20- 2	66.04	167.8	140.6	64.0
18	N.-P.E.	18- 5	59.05	150.0	124.4	56.6
19	N.-P.E.	18- 8	62.30	158.3	134.6	61.2
20	P.E.	18- 6	62.60	159.0	110.1	50.0
21	N.-P.E.	19- 9	63.19	160.5	107.9	49.0
22	N.-P.E.	18- 7	66.34	168.5	108.4	49.3
23	N.-P.E.	18-11	64.47	163.8	118.5	53.9
24	N.-P.E.	18- 4	61.22	155.5	116.7	53.0
25	N.-P.E.	18- 8	62.40	158.5	106.0	48.2
26	N.-P.E.	18- 8	69.39	176.3	145.8	66.3
27	N.-P.E.	18-10	66.83	169.8	121.9	55.4
28	N.-P.E.	18-10	61.71	156.8	148.9	67.7

*Major: P.E. = Physical Education; N.-P.E. = Non-Physical Education.

TABLE LXXXVII

RAW DATA ON PUBIC SKINFOLD, PER CENT BODY FAT, FAT-FREE BODY WEIGHT, AND RELATIVE WEIGHT

Subject	Pubic Skinfold in Centimeters	Per Cent of Body Fat	Fat-Free Body Weight in Kilograms	Per Cent of Standard Weight
1	5.7	24.0	47.1	106.6
2	4.0	21.5	41.2	93.1
3	17.0	28.5	45.1	111.7
4	6.3	27.0	46.6	120.9
5	5.7	23.0	45.4	99.8
6	6.0	22.5	42.1	95.7
7	14.3	25.0	45.2	101.9
8	15.3	24.5	42.5	95.1
9	14.0	26.5	48.1	108.9
10	10.7	24.0	45.7	98.5
11	18.7	28.0	49.4	112.7
12	9.3	26.0	49.9	114.0
13	5.0	23.0	48.1	99.6
14	8.0	26.5	46.0	105.6
15	7.0	23.5	39.9	84.7
16	36.0	25.0	39.8	99.4
17	5.0	23.5	48.9	103.4
18	11.0	28.0	40.7	121.9
19	9.0	27.0	44.7	119.1
20	5.0	21.5	39.3	91.7
21	9.7	22.5	38.0	93.0
22	5.0	20.5	39.2	85.3
23	5.0	22.5	41.8	98.8
24	16.7	26.5	39.0	107.0
25	12.0	23.5	36.9	93.8
26	11.0	25.0	50.0	105.6
27	3.0	21.5	43.5	95.9
28	21.6	31.7	46.3	128.4

TABLE LXXXVIII

RAW DATA ON PREDICTED SPECIFIC GRAVITY, PONDERAL INDEX, AND DAILY CALORIC EXPENDITURE

Subjects	Predicted Specific Gravity	Ponderal Index	Daily Calorid Expenditure
1	1.052	12.69	1649
2	1.055	13.12	2010
3	1.043	12.22	1429
4	1.044	11.80	2261
5	1.052	12.88	2095
6	1.053	12.94	1682
7	1.047	12.84	1960
8	1.049	13.15	1377
9	1.045	12.58	2975
10	1.050	13.29	2208
11	1.042	12.58	2772
12	1.046	12.32	2688
13	1.052	13.17	1591
14	1.049	12.69	992
15	1.057	13.62	1196
16	1.039	12.81	1252
17	1.051	12.72	1735
18	1.042	11.86	733
19	1.044	12.17	2150
20	1.055	13.07	1572
21	1.053	13.30	614
22	1.057	13.94	371
23	1.053	13.13	621
24	1.045	12.57	651
25	1.051	13.22	1381
26	1.048	13.22	2201
27	1.055	13.50	1273
28	1.035	11.66	1076

TABLE LXXXIX

RAW DATA ON STRENGTH

Subject	Total Strength in Kilograms	Hip Flexion Strength	Hip Extension Strength	Knee Extension Strength	Shoulder Extension Strength	Elbow Extension Strength	Ankle Extension Strength	Elbow Flexion Strength	Shoulder Horizontal Flexion Strength	Shoulder Flexion Strength	Trunk Flexion Strength	Trunk Extension Strength
1	572	72.72	65.50	117.61	30.25	20.62	74.42	35.75	19.50	32.00	49.12	22.50
2	415	76.70	52.50	66.84	30.25	16.00	38.50	25.50	16.25	26.62	25.50	38.50
3	392	57.88	29.75	76.70	25.12	19.50	39.00	31.00	18.88	25.50	20.88	23.75
4	272	36.00	39.00	57.25	13.88	13.00	22.00	21.75	11.88	19.75	14.13	45.50
5	350	41.75	50.62	65.50	21.25	15.75	36.25	25.75	15.50	32.00	40.88	20.00
6	426	55.13	48.50	54.75	33.00	24.25	42.88	30.25	23.50	43.38	18.88	50.63
7	421	53.50	42.00	71.59	33.92	19.50	40.88	27.62	16.00	25.50	38.12	50.62
8	435	70.82	57.25	55.00	27.00	16.25	34.87	25.87	15.75	27.62	51.50	52.00
9	496	79.54	47.00	81.25	38.38	23.75	59.25	32.50	24.65	35.50	24.68	37.88
10	326	50.00	47.75	51.38	21.75	14.75	24.25	25.88	15.25	20.88	18.75	35.38
11	556	94.32	60.00	109.09	31.25	20.00	61.65	30.25	22.50	42.88	40.88	52.88
12	415	58.62	45.50	77.26	25.00	20.00	38.50	27.00	16.00	33.00	27.25	46.25
13	335	52.25	40.13	55.13	20.63	15.25	31.50	23.50	13.13	18.13	23.25	34.88
14	433	71.59	64.00	81.81	29.75	15.00	36.88	33.38	20.00	37.38	20.00	22.75
15	291	36.75	47.65	41.25	15.25	9.75	23.50	21.25	12.25	29.25	24.63	29.38
16	373	62.75	42.00	61.50	22.00	11.88	40.50	23.00	18.62	24.62	35.38	20.62
17	304	37.00	26.35	39.25	21.87	16.50	26.50	20.00	12.50	28.00	33.37	41.75
18	413	64.25	44.88	57.25	33.00	26.88	52.89	32.00	23.00	29.25	26.88	23.00
19	361	51.38	27.25	49.88	26.50	16.75	51.75	22.25	15.25	25.38	60.00	14.75
20	400	52.88	44.00	62.75	26.63	19.50	50.63	25.13	21.75	26.63	31.00	40.13
21	372	52.25	39.50	45.50	32.00	17.00	62.75	25.50	16.25	26.63	28.00	24.50
22	243	29.58	34.38	40.63	13.00	12.00	26.25	14.75	12.38	15.25	24.75	19.50
23	318	47.00	37.25	47.00	28.89	15.25	41.38	23.00	18.63	25.88	24.63	15.25
24	332	54.50	34.38	57.25	23.25	13.00	41.38	25.13	10.75	20.00	29.38	23.75
25	300	43.38	30.25	60.13	19.75	9.75	25.75	21.75	11.75	17.88	33.00	25.75
26	406	59.25	53.65	78.41	22.25	18.63	45.50	25.89	17.00	21.25	18.63	44.78
27	372	57.25	37.38	74.43	17.88	15.25	42.88	29.25	14.25	32.50	27.63	24.63
28	422	52.87	46.25	80.67	25.00	22.37	57.25	32.50	20.12	31.30	29.75	24.25

TABLE XC

RAW DATA ON TEST ONE METABOLIC RESPONSES

Subjects	Maximal Oxygen Consumption in Liters per Minute	Maximal Oxygen Consumption in Kilograms of Body Weight in Liters per Min.	Maximal Oxygen Consumption in Fat-free Kg. of Body Wt. in Liters per Min.	Time on Treadmill of Maximal Oxygen Attainment in Minutes	Heart Rate Simultaneous w/Maximal Oxygen Attain.	Heart Rate During Last Min. on Treadm.	Oxygen Pulse	R.Q. Simultaneous w/Maximal Oxygen Attainment	Maximal R.Q.	Total Time on Treadmill in Minutes
1	2.444	.03865	.05200	13:00	178	191	13.7	1.02	1.74	14.0
2	1.949	.03614	.04753	14:00	195	195	10.0	1.12	1.12	14.5
3	2.431	.03840	.05402	15:00	178	189	13.6	1.05	1.15	16.0
4	2.126	.03391	.04523	13:00	199	203	10.7	1.03	1.03	13.0
5	2.260	.03705	.05022	13:00	173	185	13.1	.97	1.18	14.0
6	1.927	.03519	.04588	14:00	207	204	9.3	1.17	1.17	14.0
7	1.908	.03193	.04240	14:00	201	200	9.5	1.10	1.10	13.5
8	1.987	.03329	.04730	16:00	180	180	11.1	1.37	1.37	15.5
9	2.985	.04402	.06218	18:00	194	194	15.4	1.00	1.03	18.0
10	2.376	.04000	.05165	16:00	195	201	12.2	1.11	1.11	15.5
11	3.119	.04520	.06365	16:00	198	199	15.3	.91	1.10	17.0
12	2.587	.03713	.05174	13:00	181	184	14.1	.99	.99	13.5
13	2.655	.04164	.05531	13:00	200	215	13.3	1.15	1.15	14.0
14	2.448	.03936	.05321	16:00	186	195	13.2	1.22	1.23	17.0
15	2.108	.04090	.05270	17:00	190	191	11.1	.98	1.03	16.5
16	2.511	.03761	.06277	17:00	193	194	13.1	.98	1.75	17.5
17	2.421	.03768	.04940	15:00	188	197	12.9	1.02	1.02	14.5
18	2.136	.03780	.05209	15:00	185	188	11.5	.95	.97	15.0
19	1.968	.03200	.04373	13:00	177	186	11.1	1.00	1.05	14.5
20	1.875	.03678	.04807	15:00	187	195	10.1	.92	1.00	15.5
21	1.647	.03327	.04334	15:00	174	174	9.5	1.16	1.17	15.0
22	1.901	.03875	.04894	13:00	200	200	9.6	1.20	1.20	13.5
23	1.798	.03376	.04280	15:00	206	187	8.7	1.20	1.20	14.5
24	2.032	.03751	.05210	15:00	194	199	10.4	.96	1.04	15.0
25	1.934	.03988	.05227	17:00	181	197	10.6	1.02	1.10	17.5
26	2.157	.03280	.04314	14:00	188	191	11.5	.92	.93	13.5
27	1.818	.03336	.04227	15:00	178	196	10.2	1.09	.95	17.0
28	1.827	.02888	.03971	13:00	190	195	9.6	.91	.98	13.0

TABLE XCI

RAW DATA ON RETEST METABOLIC RESPONSES

Subjects	Maximal Oxygen Consumption in Liters per Minute	Maximal Oxygen Consumption in Kilograms of Body Weight in Liters per Minute	Maximal Oxygen Consumption in Fat-free Kilo-grams of Body Wt. in Liters per Min	Time on Treadmill of Maximal Oxygen Attainment in Min	Heart Rate Simul-taneous w/Maximal Oxygen Attainment	Total Time on Treadmill in Minutes
1	2.268	.03684	.04825	16.0	183	16.0
3	2.586	.04106	.05746	17.0	202	16.5
4	2.148	.03450	.04570	13.0	216	14.0
9	2.669	.04058	.05560	18.0	193	18.5
15	2.149	.04234	.05372	18.0	188	17.5
18	2.053	.03649	.05007	14.0	189	14.0
20	1.811	.03548	.04643	15.0	187	15.0
24	1.993	.03677	.05110	15.0	192	15.0

APPENDIX B

DATA SHEETS USED TO RECORD AND CALCULATE MAXIMAL WORK CAPACITY, BODY COMPOSITION, AND STRENGTH

METABOLIC CALCULATION DATA SHEET

Name of Study __________

Subject (name) __________ No. ____
Major __________
Year in School __________
Height (cm) _____ Weight (kg) __________
Birthdate __________

Date __________
Time of Day __________

Treadmill Room
Temperature __________
Humidity __________

Laboratory Room
Temperature __________
B. Pressure __________

Kagr. Temp.	Bag #	Time of Bag	Finial Kafronyi	- Initial Kafronyi	+ Samp. Gas	= Kafr. Diff.	X Kafronyi Cf. 1.07	X STPD Corr.	CO_2 Read.	% CO_2	O_2 Reading	% O_2	RQ	- Corr. Vent.	True O_2 X Corr. Vent.	X Time	= O_2 l/min.	Body Wgt. (kg)	= O_2 l/min/kg	

BODY COMPOSITION--STRENGTH DATA SHEET

Name ____________________ Age (years-months) ______________

Address ____________________ Weight Kg ____________ lbs. ________

Phone ____________________ Weight ________ Build and Blood Pressure Study

Major ____________________ Height ________

Ponderal Index ______________

	1	2	3	Average
Pubic Skinfold (mm)	___	___	___	______

Relative Weight = $\frac{\text{Actual weight}}{\text{Standard weight}}$ =

Specific Gravity (Young) S.G. = 1.0084 - .0004231 - .0003401

S.G. = 1.0084 - .0004231 $_{XI}$ -.0003401 $_{X13}$

S.G. = 1.0084 - ( ) ( )

S.G. =

Per Cent Fat of Body Weight (Rathbun-Pace)

Per Cent Fat = $100\left(\frac{5.548}{\text{Specific Gravity}} - 5.044\right)$

Per Cent Fat =

Kilograms fat = ____________ (per cent fat) x ____________ (body weight) =

Kilograms of fat-free body weight = ____________ (body weight) - ____________ (kilograms fat)

Kg. fat free body weight =

Strength (cm)	1	2	3	Average
1. Shoulder Extension	___	___	___	______
2. Elbow Extension	___	___	___	______
3. Ankle Extension	___	___	___	______
4. Elbow Flexion	___	___	___	______
5. Shoulder horizontal Flexion	___	___	___	______
6. Hip Flexion	___	___	___	______
7. Hip Extension	___	___	___	______
8. Shoulder Flexion	___	___	___	______
9. Trunk Flexion	___	___	___	______
10. Trunk Extension	___	___	___	______
11. Knee Extension	___	___	___	______
Total Strength	___	___	___	______

APPENDIX C

FORMULAS USED TO COMPUTE SPECIFIC GRAVITY, PER CENT FAT, FAT-FREE BODY WEIGHT, AND PONDERAL INDEX

FORMULAS USED FOR PER CENT OF FAT OF BODY WEIGHT, KILOGRAMS OF FAT OF BODY WEIGHT, PER CENT OF FAT-FREE BODY WEIGHT, AND PONDERAL INDEX

(1) PER CENT FAT OF BODY WEIGHT*

$$\text{Per cent fat} = 100 \left(\frac{5.548}{\text{specific gravity}} - 5.044\right)$$

(2) KILOGRAMS OF FAT OF BODY WEIGHT

$$\text{Kilograms fat} = \text{per cent fat} \times \text{body weight}$$

(3) KILOGRAMS OF FAT-FREE BODY WEIGHT

$$\text{Kg fat-free body wt.} = \text{body weight} - \text{kg fat}$$

(4) PONDERAL INDEX

$$\text{Ponderal Index} = \frac{\text{Height}}{\sqrt[3]{\text{Weight}}}$$

*E. W. Rathbun and N. Pace, "Studies on Body Composition I," Journal of Biological Chemistry, 158:674, 1945.

PREDICTIONS FORMULA FOR SPECIFIC GRAVITY*

(1) Specific gravity = $1.0084 - .0004231_{X1} - .0003401_{X13}$

when X1 = skinfold on mid-abdominal line halfway between the umbilicus and the pubis (in mm)

X13 = percentage "standard" weight (average weight per height and age)**

$$\text{Per cent standard weight} = \frac{\text{actual weight}}{\text{standard weight}}$$

*C. Young, *et al.*, "Predicting Specific Gravity and Body Fatness in Young Women," *Journal of the American Dietetic Association*, 40:105, February, 1962.

**Percentage standard weight used in this formula was calculated on the basis of the predicted weight determined by the Society of Actuaries, *Build and Blood Pressure Study*, Volume I, 1959.