THE EFFECT OF A PROGRAM OF PHYSICAL ACTIVITY ON SELECTED PHYSIOLOGICAL AND ANTHROPOMETRIC PARAMETERS OF OBESE MALE ADOLESCENTS

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by

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ERRATA

Workloads 360, 720 and 1080 kpm/min should be 180, 360 and 540 kpm/min, respectively.

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CHAPTER I

THE PROBLEM

Introduction

Obesity has become one of the greatest nutritional problems of modern civilization. It has always been one of the major hazards in a type of life where economic worries were non-existent and physical exercise unnecessary. In the past, these conditions were seldom prevalent except for the small minority of the affluent. In our present society, however, high economic status is very common, and as a result obesity is now found frequently in children and adolescents (10). It has been emphasized too that obesity is more likely to persist with minor fluctuations if it occurs in the early stages of an individual's life (8, 35, 27).

It is well documented that obesity is a major obstacle to optimal health (32) and results from the permissive interaction of genetic and environmental factors or of traumatic factors with the genetic and environmental background (24). In its final analysis, it is due to an energy imbalance whereby energy input exceeds energy output resulting in a positive energy balance.

Recent investigations (2, 3, 6, 17, 18, 25, 26, 31) emphasize that reduced physical activity may be important in the pathogenesis of obesity. That is, what is known of the physical activity of obese persons indicates that physical inactivity may play a very prominent role in human obesity. Many studies (3, 4, 6, 16, 19, 34, 36) investigating physical activity of the obese agree that they are less active than persons of normal weight. Also, many have reported a much lower food intake in comparison to the nonobese (1, 6, 11, 12, 13, 14, 15, 16, 34). Mayer, a prolific writer on the problem of obesity, has emphasized that "...inactivity is the most important factor explaining the frequency of 'creeping' overweight in modern Western societies" (21).

Recent research has confirmed that a positive relationship between physical activity and "weight control" does in fact exist. Increased physical activity exerts a modifying influence upon body composition and body weight (5, 7, 9, 11, 18, 21, 28, 30, 33, 37, 38, 39, 40). Similarly, pediatricians, psychiatrists and others of late have suggested the potential importance of training in physical education and regular exercise as a vital contributor to the treatment and prevention of childhood and adolescent obesity.

Statement of the Problem

The purpose of this study was to determine the effects of a program of physical activity on selected physiological and anthropometric parameters of obese male adolescents.

Subproblems

More specifically, the study investigated:

1. The effects of a physical activity program on the exercise response to a work capacity test and on selected hematological variables of obese male adolescents.

2. The effects of a physical activity program on selected anthropometric measurements.

Definitions

For purposes of classification, the following definition is considered applicable throughout the study.

Obesity. The presence of an excessive amount of fat in the organism (23). Thus, the way to determine whether a person is obese is to measure his actual fat content. Mayer (23) has estimated that the average man should have about 10 percent of his total body weight in the form of fat. For women, 15% has been suggested. In contrast, overweight is a departure of actual weight from a height-weight standard. MacBryde (20) states that when the body is not overhydrated or dehydrated and the excess weight is due to increased fat storage, weight 10 percent above normal may be classified as moderately overweight, weight 15 percent above optimal, obese and weight 20 percent or more above optimal, seriously or dangerously obese. Total body weight is a measure of extracellular fluid, bone, muscle and fat, and any departure from average weight may be due to one or another or a combination of these body compartments.

In this study, any subject with a percent body fat of 20 and above was classified as obese. Initially, in the experimental group, percent body fat ranged from 23 to 40, and in the control group, 26 to 42 (Appendix C). Percent body fat was calculated according to the method of Pascale et al. (29) whereby the iliac and triceps skinfold measurements were fit into a prediction equation to obtain density with a corresponding percent fat reading from a table.

Delimitations

This study investigated the effects of a physical activity program (lacrosse) on selected physiological and anthropometric parameters of obese male adolescents. The experimental group was composed of 11 obese students from the Académie de la Salle, Ottawa, Ontario. The control group was composed of 10 obese students from the University of Ottawa High School, Ontario. In both groups, all subjects were male, and between 14 and 17 years of age.

The experimental and control groups were pretested the last two and first two weeks of November and December 1970, respectively. The lacrosse program for the experimental group began December 2, 1970 and terminated April 30, 1971 following which both groups were retested.

Testing of the subjects consisted of a preliminary medical examination, blood analysis (hematocrit, hemoglobin, cholesterol, thyroxine), a work capacity test and selected anthropometric measurements.

The initial or pretest data for all tests were subjected to an analysis of variance to determine whether there existed any significant differences (.01 and .05 levels) between the experimental and control groups at the initial testing sessions. If significant differences did exist, the analysis of covariance was employed to determine if any significantly different changes (.01 and .05 levels) existed between the two groups at the retesting sessions. The analysis of variance was used for the final or post-test data if the groups did not differ significantly at the initial testing sessions.

Limitations

1. The subjects employed in this study were selected from male adolescents who were judged by their school nurse on the basis of height, weight and physical appearance to be obese, and whose parents submitted their permission for the participation of their son in a physical activity program (lacrosse).

2. The number of subjects was limited by the criterion of being obese.

3. The subjects were selected from two Ottawa, Ontario Secondary Schools. Those obese male adolescents from the Académie de la Salle were designated as the experimental group, and those from the University of Ottawa High School as the control group. No random selection was carried out.

4. The investigator had no control over the experimental treatment (lacrosse program) on which the results of the study depended.

5. The success of the experimental treatment and hence, the study, depended also on the fairly consistent attendance of the experimental group in the lacrosse program.

6. The subjects of both the experimental and control groups took regular physical education classes as part of their normal school curriculum.

Significance of the Study

A minimal and negligible role was of late delegated to exercise in the treatment of obesity. Literature dealing with the etiology of obesity points out that inactivity is a major factor. The beneficial effects of increased physical activity on various parameters such as body weight and body composition emphasize the positive relationship that exists between physical activity and weight control. Perhaps this study will give support to what evidence already exists of this, and in addition reveal even more information on the possible remedial effects of increased physical activity patterns, particularly in obese adolescents.

REFERENCES

Chapter I

1. R.Beaudoin and J. Mayer, "Food Intake of Obese and Non-Obese Women," Journal of the American Dietetic Association, 29: 29-33, 1953.

2. H. Bruch, "Physiological and Psychological Aspects of Food Intake of Obese Children," American Journal of Disabled Children, 59: 739-781, 1940.

3. B. Bullen, R.B. Reed and J. Mayer, "Physical Activity of Obese and Non-Obese Adolescent Girls Appraised by Motion Picture Sampling," American Journal of Clinical Nutrition, 14: 211-223, 1964.

4. A. Chirico and A.J. Stunkard, "Physical Activity and Human Obesity," New England Medical Journal, 263: 935-940, 1960.

5. G. Christakis, S. Sajecki, R.W. Hillman, E. Miller, S. Blumenthal and M. Archer, "Effect of a Combined Nutrition Education and Physical Fitness Program on the Weight Status of Obese High School Boys," Federation Proceedings, 25: 15-19, 1966.

6. C.B. Corbin and P. Pletcher, "Diet and Physical Activity Patterns of Obese and Non-Obese Elementary School Children," Research Quarterly, 39: 422-429, 1968.

7. T.K. Cureton, "Anatomical, Physiological and Psychological Changes Induced by Exercise Programs (Exercise, Sports and Games) in Adults," Exercise and Fitness (Chicago: The Athletic Institute, 1959), pp. 152-182.

8. S. Davidson and R. Passmore, Human Nutrition and Dietetics, 3rd edition (Edinburgh: E. & S. Livingstone, Ltd., 1966).

9. J. Dempsey, "The Effects of Caloric Restriction and Muscular Activity on Body Composition," (unpublished paper, University of Alberta, 1962).

10. J.V.G.A. Durnin, "The Influence of Nutrition," Canadian Medical Association Journal, 96: 715-718, 1967.

11. P.C. Fry, "Comparative Study of 'Obese' Children Selected on Basis of Fat Pads," Journal of Clinical Nutrition, 1: 453-467, 1953.

12. M.C. Hampton, L.C. Shapiro and R.L. Huenemann, "Helping Teen-age Girls Improve their Diets," Journal of Home Economics, 53: 835-838, 1961.

13. M. Hinton, "Factors Related to the Eating Behaviour and Dietary Adequacy of Girls 12 to 14 Years of Age," (unpublished Ph.D. dissertation, Iowa State University and Technology, 1962).

14. M.A. Hinton, E.S. Eppwright and H. Chadderdon, "Eating Behaviour and Dietary Intake of Girls 12 to 14 Years Old," Journal of the American Dietetic Association, 43: 223-227, 1967.

15. R.L. Huenemann, M.C. Hampton, L.C. Shapiro and A.R. Behnke, "Adolescent Food Practices Associated with Obesity," Federation Proceedings, 25: 4-10, 1966.

16. H.L. Johnson, B.S. Burke and J. Mayer, "Relative Importance of Inactivity and Overeating in the Energy Balance of Obese High School Girls," American Journal of Clinical Nutrition, 4: 37-44, 1956.

17. H.L. Johnson, B.S. Burke and J. Mayer, "The Prevalence and Incidence of Obesity in a Cross-Section of Elementary and Secondary School Children," American Journal of Clinical Nutrition, 4: 231-238, 1956.

18. A. Keys, "Body Composition and its Change with Age and Diet," Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 18-28.

19. G. Larsen, "Treatment of Obesity," Tijdsche. f. d. morske, 69: 442-446, 1949.

20. C.M. MacBryde, "The Diagnosis of Obesity," The Medical Clinics of North America, 48: 1307-1316, 1964.

21. G.V. Mann, K. Teel, O. Hayes and A. McNally, "Exercise in the Disposition of Dietary Calories," New England Journal of Medicine, 253: 349-355, 1955.

22. J. Mayer, "Exercise and Weight Control," Exercise and Fitness (Chicago: The Athletic Institute, 1959), pp. 110-121.

23. J. Mayer, "Obesity: Physiologic Considerations," American Journal of Clinical Nutrition, 9: 530-537, 1961.

24. J. Mayer, "Obesity: Etiology and Pathogenesis," *Postgraduate Medicine*, 25: 623-634, 1959.

25. J. Mayer, N.B. Marshall, J.J. Vitale, J.M. Christensen, M.B. Mashayekhi and F.J. Stare, "Exercise, Food Intake and Body Weight in Normal Rats and Genetically Obese Adult Mice," *American Journal of Physiology*, 177: 544-548, 1954.

26. J. Mayer, P. Roy, and K.P. Mitra, "Relation Between Caloric Intake, Body Weight and Physical Work in an Industrial Male Population in West Bengal," *American Journal of Clinical Nutrition*, 4: 169-175, 1956.

27. R.A. McCance, "Overweight and Underweight. I. Causes," *Lancet*, 2: 685-690, 1953.

28. L.B. Oscai and B.T. Williams, "Effects of Exercise on Overweight Middle-Aged Males," *Journal of the American Geriatrics Society*, 16: 794-797, 1968.

29. L. Pascale, M.I. Grossman, M.S. Sloane and J. Frankel, "Correlations Between Thickness of Skinfolds and Body Density in 88 Soldiers," *Human Biology*, 28: 165-176, 1956.

30. F.B. Roby, "Effect of Exercise on Regional Fat Accumulation," *Research Quarterly*, 33: 273-277, 1962.

31. M.R. Rony, *Obesity and Leaness* (Philadelphia: Lea and Febiger, 1940).

32. R.P. Schlegel, "Obesity as a Factor in Health, Disease and Longevity," (unpublished research paper, University of Illinois, 1966).

33. S. Sprynarova and J. Parizkova, "Change in the Aerobic Capacity and Body Composition in Obese Boys After Reduction," *Journal of Applied Physiology*, 20: 934-937, 1965.

34. P.A. Stefanik, F.P. Heald and J. Mayer, "Caloric Intake in Relation to Energy Output of Obese and Non-Obese Adolescent Boys," *American Journal of Clinical Nutrition*, 7: 55-61, 1959.

35. J.M. Strang, "Obesity," *Diseases of Metabolism*, 5th edition, G.G. Duncan, editor (Philadelphia: W.B. Saunders Company, 1964), pp. 693-804.

36. A. Stunkard, "Physical Activity, Emotions and Human Obesity," American Practitioners and Digest of Treatment, 10: 1500-1501, 1959.

37. C.W. Thompson, "Changes in Body Fat Estimated from Skinfold Measures of Varsity College Football Players during a Season," Research Quarterly, 30: 87-93, 1959.

38. C.W. Thompson, E.R. Buskirk and R.F. Goldman, "Changes in Body Fat Estimated from Skinfold Measures of College Basketball and Hockey Players during a Season," Research Quarterly, 27: 418-430, 1956.

39. R.A. Walker, "Changes in Body Fat as Computed from Skinfold Measures of College Track and Field Athletes during a Season of Competition and Training," (unpublished M.Sc. thesis, South Dakota State College, 1959).

40. M.S. Yuhasz, "The Effects of Sports Training on Body Fat in Man: With Predictions of Optimal Body Weight," (unpublished Ph.D. dissertation, University of Illinois, 1962).

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The purpose of this study was to determine the response of selected physiological and anthropometric parameters of obese male adolescents engaged in a 5 month lacrosse program.

Evidence has been increasing to support the contention that reduced physical activity may be important in the pathogenesis of obesity. That is, what is known of the physical activity of obese persons indicates that physical inactivity may play a very prominent role in human obesity. As a result, an increase in physical activity patterns of the obese is receiving support as a method of weight control. The literature confirming the beneficial effects of regular physical activity of varying intensities in normal people is abundant; however, the literature concerned with the obese and the effect of regular physical activity is limited. There remains much more research to be completed before the full potential of exercise as a method of weight control can be realized.

The purpose of this chapter is to present the published literature directly and indirectly related to this study. The following subjects will be discussed:

The Multiple Etiology of Obesity.

Physical Work Capacity and Maximal Oxygen Intake.

History of the Sjostrand Test.

Maximum Oxygen Intake, Body Weight and Various Components of Body Composition.

The Effect of Training on Maximal Oxygen Intake and Physical Work Capacity.

The Effects of Physical Activity on Body Weight and Body Composition.

Metabolic Cost of Exercise in the Obese.

Cholesterol.

Thyroxine (T_4).

The Multiple Etiology of Obesity

Obesity, in its final analysis, is the result of an overall inflow of energy which has exceeded the overall outflow, with a resultant retention in the body of the excess energy as fat (35). This follows from the First Law of Thermodynamics or Law of Conservation of Energy which states that energy can neither be created nor destroyed; what disappears in one form, reappears in another (201). When one speaks solely in terms of energy equilibra, the end result of a balance sheet is indicated, in which the only considerations involved are total caloric intake, total caloric output and change in body weight. From this point of view all obesity is necessarily of one kind, that is, a positive energy balance phenomenon (i.e. $I > O \rightarrow +$ body fat).

"To say that obesity is due to overeating, which is true, is as meaningful to account for alcoholism by ascribing it to 'overdrinking'" (126). However, in the sense that changes in caloric intake, caloric expenditure or both can be influenced directly or indirectly by genetic, traumatic, dietary, psychological, activity, socio-cultural and other factors, obesity with a multiple etiology arises. Overeating is not a cause, but rather a means to obesity. Even the fact that weight reduction in the majority of people is usually unsuccessful indicates that the etiology of obesity is a very complex matter.

Literature reviewing the etiology of obesity is abundant and it has been aptly summarized by Mayer (121) who has contributed much of the basic work in the elucidation of the possible causes, types, and mechanisms of obesities. Mayer has classified (120, 121) obesities according to their causes (etiology) and according to the mechanisms of their development (pathogenesis). Etiologically, the obesities may be due to genetic, traumatic or environmental factors. For obesity to develop, there has to be a permissive interaction of genetic and environmental factors, or of traumatic factors with the genetic and environmental background. Pathogenetically, Mayer classifies obesities as either regulatory, in which the primary impairment is in the central mechanism regulating food intake, or metabolic, in which the primary lesion is an inborn or acquired error in the carbohydrate and fat metabolism of the tissue per se. In the first case, habitual hyperphagia may lead to secondary metabolic abnormalities. In the second case, peripheral metabolic dysfunction may, in turn, interfere with the proper functioning of the central nervous system.

Genetic Factors. It is generally believed that there are important genetic aspects in the production of the obese state. From the animal experiments by Mayer (120, 122, 124) and others (74), it is obvious that there may be a number of physical bases for obesity, although it has not always been easy to show the human counterparts of some of these obesities. That obesity does "run in families" has been well founded, as Mayer (120, 122, 124) has pointed out in reviewing the studies of previous investigators. He indicates that parents of average weight have a 9 percent chance of having an obese offspring; one obese and one average parent raises the probability to 50 percent, while the chances with both parents obese is 73 percent. Furthermore, studies of twins have produced more cogent evidence of the fact that genetic factors do influence body weight and may cause obesity. Mayer (120) points out that as in other genetic conditions, pathologic or other characteristics which are always or nearly always present in both identical twins, but rarely or never present in both fraternal twins, are hereditary. The studies of Newman and von Verchuer, as reviewed by Mayer (120) reported that identical twins had much more similar weights than fraternal twins; when identical twins were reared in different environments, differences in weight increased.

Thus, the aforementioned findings may be in part due to environmental factors, but they strongly suggest a "genetic predisposition".

Although there is evidence to support the supposition that there are genes which predispose to obesity, the mode of transmission is obscure and the mechanism by which the inherited tendency is mediated is not understood (122).

Traumatic Factors. In man, and in animals particularly, obesity can be inducted by the injection of chemicals, by hormonal treatment, by surgical interference with nervous centres and by psychologic trauma (120, 122, 126). These means of inducting obesity are referred to as traumatic factors in the etiology of obesity. Mayer (120) comments that although in these cases, "the origin of the disturbance is related to a definite traumatic event, the mechanism of genetically determined obesities may in some cases proceed from similar (inherited) endocrine, nervous or psychosomatic abnormalities, or predispose to greater sensitivity to one or the other of these traumas".

Among traumatic obesities described (120, 122, 126) are those resulting from surgical damage (to hypothalamus, frontal lobe etc., in man and animals) and chemical damage (by introducing goldthioglucose into the hypothalamus and other parts of the central nervous system which cause lesions in experimental animals culminating in hyperphagia). Endocrine factors in obesity previously were overemphasized (122); it was believed very early that obesity could be cured purely along endocrine lines. Today, although we know that hypopituitarism or hypothyroidism does not cause obesity, it is known that a number of hormones influence food intake and fat metabolism; thus, any endocrine disturbance which affects metabolism of carbohydrate usually affects regulation of food intake.

Mayer (120) has reported that psychological factors, according to many researchers, seem to play a frequent and important role, often the main role in the etiology of obesity. In the studies of many of these researchers, Mayer criticized the lack of proper control (in psychiatric ones), the confusion in psychiatric literature between psychologic effects of obesity and "causal" factors, and the possibility that in many cases in which the primary cause of obesity is psychologic, "...physiologic intermediaries are involved so that the relation of observed behaviour to primary cause is distant".

<u>Environmental Factors: Dietary Factors</u>. Until recently, little reliable information was available comparing nutrient selection or meal patterns of obese persons with those of similar groups of nonobese persons. It has often been stated that the obese eat more frequently, eat very large quantities of food in one sitting, derive a large proportion of their caloric intake from evening meals and snacks, or consume most of their food in one meal. However, this major importance of

overeating in obesity has been too widely accepted without confirmatory evidence. Recent investigations, however, have began to elucidate new evidence on these facts.

In 1940, Bruch (24) reviewed early studies on food intake in adults and children. Generally, an excessively large and poorly balanced diet with a majority of starchy carbohydrates in obese adults was indicated in most studies; also, caloric intake was in some cases excessive and in other cases, very small. In her own investigations and in others, Bruch found that the food intake of most obese children was far in excess of that of nonobese children.

More recently, in studying the diet and activity patterns of 28 obese and 28 matched nonobese high school girls, Johnson <u>et al</u>. (92) found the caloric intake of the former group to be significantly lower than that of the latter group, while the obese girls were significantly less active. Although both groups were relatively inactive, the differences in the amount of activity between them was "...much more important than overeating in the development and maintenance of obesity". A subsequent study by Stefanik <u>et al.</u> (186) similarly showed that adolescent boys ate significantly less than nonobese controls.

In a pilot study in 1961, Hampton <u>et al</u>. (77) reported that obese teenage girls in the A_4 and A_3 channels of the Wetzel Grid consumed fewer calories and smaller amounts of essential nutrients than their leaner classmates. Huenemann et al. (84, 85) corroborated these results in a large study involving 950 teenagers of which 10% were Oriental, 30% Negro and the remainder Caucasian. In addition, boys classified as obese had lower intakes of the nutrients calcium, iron, thiamin, riboflavin and ascorbic acid than extremely lean, lean, average and beginning obesity groups. Furthermore, obese girls ranked lower than the other groups in thiamine, niacine and ascorbic acid. Mean protein intakes for male and female fat classes (mildly and markedly obese) were higher than the recommended Dietary Allowances of the National Research Council.

Corbin and Pletcher (37), however, reported no significant differences in the number of calories consumed in 50 elementary school children divided into 4 groups (low fat, low average fat, high average fat and obese). Also, no significant differences between the groups in relation to the amount of fat, protein or carbohydrate were found. Similarly, Fry (68) found that obese children selected on the basis of fat pads, did not have a higher average caloric intake than comparable nonobese children.

Beaudoin and Mayer (14), in studying a group of obese women, found that the average calorie intake was derived from the same proportion of calories from fat (37%) and carbohydrate (49%) as that of a nonobese control group. Both groups were reported to have a high caloric intake during the evening meal in addition to evening snacks. Eppwright et al. (62) in comparing undersize, average, and average Iowa school children, reported that undersize children had lower mean daily intakes of most nutrients than oversize children. An exception, however, were the oversize teenage girls whose diets at this period contained fewer calories, less protein, and less calcium than diets of undersize girls. In oversize boys, changes in calcium and ascorbic acid intakes were not significantly related to changes in body size. In addition, increase in nutrient intake per unit of body size was less for the oversize than for the average size boys or girls. Consumption of most nutrients by oversize boys increased significantly with body size, whereas for oversize girls consumption was only slightly related to their body size.

Environmental Factors: Exercise and Physical Inactivity. As one of the factors implicated in the etiology of obesity, exercise has been receiving increasing attention. In the "energy balance" equation, the intake of energy in the form of calories must equal the output of energy in the form of activity and metabolic needs plus or minus the storage of energy as adipose tissue. Storage in the form of fat will occur whenever the caloric output is less than input. The equation thus states that a reduction in physical activity (with all other things remaining the same) will lead to obesity.

Until recently, the importance of the lack of physical activity as an etiological factor in the development of obesity has been grossly underemphasized.

One misconception (120, 125) discounting the value of exercise was that exercise requires very little energy and thus, increased physical activity hardly changes the caloric balance. Obviously, this is not so, since tables of energy expenditure (158) illustrate that the cost of energy expenditure in activities (eg. one hour walking = 700 cal/hr.) can be quite high. The second misconception advanced the fallacy that an increase in physical activity always leads to an increase in appetite and food intake which is at least as great in energy value as the energy expended in exercise.

Mayer et al. (129), in a study using mature rats accustomed to a sedentary existence, have shown that the above is not true of low levels of energy. In the rats which were exercised on a treadmill for increasing daily periods (20 minutes to 1 hour, designated as "sedentary range"), food intake at these low durations of exercise actually decreased slightly from that of unexercised rats. Body weight also decreased. For longer durations of exercise (1 to 5 or 6 hours, designated as "normal activity"), food intake increased linearly and body weight was maintained. However, for very long durations of exercise (designated as "exhausting activity") the animals lost weight, their food intake decreased and their appearance deteriorated. A further study by Mayer et al. (130) of mill workers in India covering a wide range of physical activity, from sedentary to very hard work, corroborated the above findings. It was observed that caloric intake increased with activity only within a certain zone ("normal activity"), and below that range ("sedentary zone") a decrease in activity was not followed by a decrease in food intake but rather by an increase. Body weight also increased. Mayer suggests that a certain minimal level of physical activity is necessary for the appetite to function with precision and to adjust food intake to requirements. Passmore's (157) finding that exercising a dog on a treadmill for a short period did not increase the appetite above the sedentary level supports that suggestion.

What is known of the physical activity of obese persons indicates that physical inactivity may play a part in human obesity. It is true also, that in the obese individual, inactivity tends to establish a vicious circle. Not only does the lack of activity lead to overweight, but the overweight individual tends to become even more inactive (34).

Bruch (25) in 1940, in her early studies of obese children, commented on their relative inactivity. She stated that their apparent inhibition of activity represented a more fundamental disturbance than overeating and linked their inactivity rather to emotional factors. Bronstein _et al_. (20) found that most of the 35 obese children whom he and his coworkers studied spent most of their leisure time in sedentary activities. Peckos _et al_. (159) studying a large group of Boston children, reported that differences in body build, and more specifically in fat content and distribution, were not correlated with caloric intake. Fry (68) found that a much higher proportion of obese children than nonobese were only moderately active or inactive.

Johnson, Burke and Mayer (91) found that the onset of excessive weight gain among obese children in two Massachusetts public schools occurred mainly during the winter, thus suggesting that inactivity might be an important factor in the development of obesity. A more detailed study in which food intake and activity schedules of 28 obese high school girls were compared to a similar nonobese group of 22, showed that the obese girls ate less than normal weight controls, but spent two-thirds less time in activities involving any kind of exercise. Similarly, Stefanik _et al_. (185) reported a significantly smaller degree of participation in exercise among 14 obese adolescent boys compared to 14 matched nonobese controls attending a summer camp.

Mayer (123) has shown that the caloric surplus of obese-hyperglycemic mice during the active phase of their obesity is due primarily to the fact that they are far less active than their nonobese litter mates. When the "waltzing gene" is bred into this strain of mice, moreover, the resultant increased activity is sufficient to maintain a normal body weight.

In 1957, Dorris and Stunkard (56) attempted to measure physical activity by means of a mechanical pedometer. They found that 15 obese women walked a significantly shorter distance over a period of one week than did a matched group of nonobese control subjects. Further studies by Stunkard (188), Chirico and Stunkard (33) and Stunkard and Pestka (189) utilizing a mechanical pedometer corroborated these findings.

Bullen et al. (28) using a technique developed for time-motion studies in industry and involving the taking of a number of photographs which are then used as a basis for the estimation of caloric expenditures based on the particular pose represented, demonstrated that the average obese adolescent girl expends much less energy during "exercise" periods than does her nonobese counterpart. The obese girls were aware that they were inactive though they had no conception of the degree of their inactivity. They seemed totally unaware that they might not like physical activity.

More recently, Corbin and Pletcher (37) studied the caloric intake and activity patterns of 50 fifth grade students by seven-day diet recall records and filming during games and free play. They concluded that the relative inactivity of the obese children and the relatively similar diets of all children regardless of body fat, as well as a significant negative relationship between activity indexes and body fat tend to support the contention that inactivity may be as important or more important than excessive caloric intake in the development and maintenance of childhood obesity.

Causes of Physical Inactivity. There have been few studies of the causes of inactivity in children. These could be physiological, psychological, or both, or an environment which makes inactivity acceptable (217). Bullen et al. (27) compared the attitudes of a group of obese adolescent girls attending a summer camp with those of a similar group of nonobese adolescent girls. The response of the nonobese group to a questionnaire implied a family life of sociability and unity, and that they had little difficulty separating from the family. In contrast, the obese group depicted a less unified family which the child was afraid to leave. They seemed quite concerned about food-getting, but more often than was true in the nonobese group they linked it with unpleasant consequences. The obese girls said they ate more than others and thought it was the cause of their obesity. In a more recent study, Canning and Mayer (32) found similar attitudes in female adolescents. The importance of activity, diet and eating appropriate foods rather than dieting alone was emphasized more by the obese than the nonobese in a questionnaire.

Christakis et al. (34) point out that inactivity and lack of participation in sports leads to withdrawal of the obese adolescent from the peer group with eventual exclusion from normal group activities because of inability to conform to group norms. The obese adolescent finds social adaptation with his peers increasingly difficult and tends to withdraw further into himself and to direct his interests to solitary pursuits that further reduce his inactivity. In such a situation, food may be turned to as a form of oral gratification to compensate for such emotions as frustration and envy.

A possible physiological cause for concommitant effect of inactivity has been suggested by the study of Wenzell, Stults and Mayer (209). They found that obese children in an outpatient adolescent clinic population had a significantly lower serum iron (with normal hemoglobin) than nonanemic, nonobese subjects. Similar differences between larger groups of obese and nonobese adolescent girls at a summer camp were found by Seltzer and Mayer (177). Mayer (127) points out, however, that whether these low serum iron values are indicative of low myoglobin values and low values for iron-containing pigments other than hemoglobin is not known; if so, they might indicate a situation in which exercise would be unconsciously avoided.

Familial, Socioeconomic and Cultural Factors. Bryans (26) suggests that the very fact that chronic diseases which could interfere with general nutrition and growth have decreased, has resulted in a higher trend towards obesity. Advanced technology of food production and distribution, the large availability of food, an affluent society and constant advertising on increased food consumption most likely have contributed to this trend.

Parental occupation with the health of children often results in direct overfeeding, which may "...eventually be metabolically and psychologically self-perpetuating" (122). Based on rat studies, many investigators believe that overfeeding in childhood produces an excess of fat cells that are a permanent part of the body (216). Furthermore, it is felt that feeding practices of most mothers are out of date, that is, they are more suited to the past century's active life than today's sedentary style of life. Wyden (216) reviewed an experiment by Crawford in which it was found that fat rats from small litters not only grew fat faster than their leaner mates but also died an earlier death. The author concluded that "pediatricians and parents may unwillingly be building obsolescence into babies, with the resultant effect of a race of fat people with a short-life span". Other studies have revealed food being used by mothers as a reward, and too large an ingestion of "empty" calories in the form of candy and soft drinks by preschool children (216).

In many societies food is a symbol of economic security, and any social events or otherwise are usually accompanied by food with the resultant effect of individual forced-feeding (122).

Moore _et al_. (145) in studying the relationship between obesity and mental health on 1660 subjects in New York City, found the prevalence of obesity to be 7 times higher among women reared in the lowest socioeconomic category compared to those reared in the highest category; among the men, the same relationship existed, but to a lesser degree.

More recently, Huenemann et al. (84) reported obesity to be more prevalent among girls of a low economic group in a study involving 950 teenagers of which 10% were Oriental, 30% Negro and the remainder Caucasian. Also, proportionately more Negroes than Caucasians or Orientals were obese.

Physical Work Capacity and Maximal Oxygen Intake.

The terms physical fitness, physical condition , physical work capacity and maximal oxygen intake (aerobic capacity/aerobic power) are often used synonomously in the literature. Although similar to some extent, they are not, however, synonyms.

Sjostrand (180) has defined physical work capacity, pointing out that it is not related to one single function, but directly or indirectly, is dependent upon a number of functions. Some of these include:

1. The ability to develop considerable muscular strength.

2. The maximal oxygen consumption. "The ability to perform work demanding a great effort during a relatively short period of, for instance, some minutes may be limited by the oxygen transport capacity, that is, the maximal volume of oxygen which can be transported from the lungs to the active muscles" (180). The ability for high oxygen consumption is determined by many factors including lung function, the blood's oxygen capacity, stroke volume of the heart and maximal pulse frequency during work.

3. The adaptation of the respiratory and circulatory systems during work. The ability is determined, for example, by the ability to maintain sufficient pulmonary ventilation and cardiac output in addition to relative steady state in respect of the gases of the blood, blood pressure, pulse rate and vasomotor tonus in prolonged exercise. During brief work, but more so during prolonged work, the adaptation of the circulation may be the limiting factor in working capacity.

4. The amount of chemical energy reserves in the working muscles. Muscles accomplish work under aerobic and anaerobic conditions. "If a high working intensity is demanded, which can only be maintained for a short time, the sum of the anaerobic and aerobic energy release determines the work performed, and this is dependent on the aerobic and anaerobic metabolic processes as well as on the oxygen supply" (180). Low intensity work performed over a long time period, however, is only dependent on the chemical energy supply for aerobic work in the active muscles; that is, oxygen supply is not a limiting factor.

Most physiologists generally agree that maximal oxygen consumption is the best single physiological indicator of an individual's capacity for prolonged physical work (9, 10, 81, 132, 140, 193). It is an index of maximal cardiovascular-respiratory function, provided pulmonary function is normal (140).

Astrand (8), Rodahl et al. (172) and others (5) have suggested that maximal oxygen intake is probably the best measure of an individual's physical fitness. And Hettinger et al. (81), Balke and Ware (12) and Taylor (191) would seem to agree, providing the definition of physical fitness is restricted to the capacity of the individual for prolonged heavy work. The difference between physical work capacity and physical condition is pointed out by Astrand (8):

> Work capacity is a synthesis of aerobic and anaerobic capacity, mechanical efficiency and physical condition whereas physical condition states how the circulation respiration, muscles etc. are fit for hard work of long duration. The heaviness of the work must be related to the individual's working capacity. Thus, working capacity is quantitative and physical condition is more qualitative.

Strom (187) has defined maximal oxygen intake ($\dot{V}O_{2\ max}$) as "the highest oxygen uptake that a healthy person can attain during exhaustive ('maximal') muscular exercise of approximately 3-6 minutes duration, when breathing air at approximately sea level, and working on a bicycle ergometer or treadmill, or performing similar types of exercise which activate large muscle groups". Furthermore, maximal oxygen uptake is a plateau value which cannot be increased by further increase of the work load.

Sjostrand (180) has recently commented on the error of assuming that physical work capacity and maximal oxygen consumption are synonymous. He states that the maximal oxygen consumption is not an "absolute" measure of the capacity of the lungs and circulation to take up and transport oxygen; rather, it may be dependent on the capacity of the active muscles. Furthermore,

> ...it is even less a measure of the ability to maintain a high working intensity for a long period. A certain oxygen uptake...is essential for maintaining a high working intensity not only during a short period but during prolonged work as well and therefore for the physical working capacity in its true sense. But it is not true that the ability to work during a prolonged period what we usually call endurance is a function of the maximal oxygen uptake. The longer an exercise can be performed, the lower must the working intensity be, i.e. the lower is the oxygen uptake per time in relation to the maximal oxygen uptake .

Taylor et al. (193) point out that when an investigator examines work capacity he investigates work load at a pre-determined minute pulse rate, while the investigator examining maximal oxygen intake measures cardiac capacity. For work capacity submaximal work loads are used, but for maximal oxygen intake, the subject works close to a maximal load. Wahlund (204) demonstrated that at a heart rate of 170 beats per minute, physical work capacity is approximately 80% of the value of the maximal oxygen intake. Others (9, 11, 40, 179, 193) support this position.

Measurements of maximal oxygen uptake and physical work capacity usually employ two general types of tests: a) maximal tests and, b) submaximal tests. Exercise physiologists put much faith in the measurement of maximal oxygen uptake (aerobic capacity) as a good estimator of physical work capacity (9, 81, 193). The direct measurement of maximal oxygen uptake involves very complex techniques and equipment, it is very time-consuming and has the disadvantage of requiring from the subjects exhaustive efforts (4); that is, exercise of increasing severity is performed until no further increase of oxygen intake occurs (64). For these reasons, many indirect methods (submaximal tests) for determining maximal oxygen uptake have been developed. Almost all these methods of assessing submaximum performance are based on the readily demonstrable linear relationship between heart rate and either steady-state oxygen consumption or equivalent work rate, ranging from a certain minimal level of effort to $\dot{W}_{max}$ (maximum aerobic work) (6). Thus, submaximal tests can be divided into two distinct groups depending upon the criteria used for judging when the individual has reached his maximum effort, for example, a) those tests (10) based upon the measurement of heart rate and the measurement (or estimate) of oxygen consumption at one or more rates of work, and b) those tests (4, 81, 118, 204) based upon the increase in heart rate with successive increments in work rate, either on a bicycle ergometer or a step test. The rates of work are increased every two or three minutes until the subject's heart rate reaches 170 or 180 beats per minute, or until he is exhausted.

Maximal oxygen consumption can then be estimated from the submaximum test results in two ways (64): 1) the results may be plotted in the form of a curve, which is extrapolated to a predicted maximum heart rate; the corresponding oxygen consumption ($\dot{V}O_{2_{max}}$) is then read off. The predicted heart rate should take the subject's age and sex into account, and 2) the pulse rate is measured at one or more submaximum loads, together with the corresponding oxygen consumption or work rate, and $\dot{V}O_{2_{max}}$ is then estimated directly from a nomogram. The results of submaximum tests may also be reported directly, without estimating $\dot{V}O_{2_{max}}$ by recording either a) the oxygen consumption or the work rate at a specified pulse level, or b) the pulse rate at a specified oxygen consumption or work rate.

Three types of methods or test instruments are currently used for the assessment of maximal oxygen uptake and physical work capacity: 1) treadmill, 2) bicycle ergometer, and 3) step test. Notwithstanding, there is no best test instrument for their measurement. Each test using these instruments has its own advantages and disadvantages (57).

History of the Sjostrand Test

One group of submaximal tests employed to measure maximal oxygen intake and physical work capacity is based upon the increase in heart rate with successive increments in work rate. A widely accepted work capacity test on the bicycle ergometer based upon these concepts has been described by Sjostrand (118).

In 1947 he reported findings on the physical working capacity of 20 workmen employed in an ore smelting works. (The test was different from the test currently employed but the basic features were present). Work loads of 300, 600, 900 and occasionally 1200 mkg/min. were employed for a ten minute interval at each work level except the last, which was either six or four minutes. This work was continued at a rate of 300 m/min. until the heart rate was either greater than 175 beats per minute or the increase between the first determination and the last was more than 10 beats per minute. Upon arrival at this critical level, the next lower work load was then considered the highest which could be maintained without signs of insufficiency of the respiratory or circulatory organs. In this same article (118), Sjostrand stated that about two thousand work capacity tests of the kind described above were carried out at the Caroline Hospital, Stockholm, but he does not indicate any earlier reports of this type of test in the literature. Bengtsson (15) indicates that the method for investigating circulatory and respiratory conditions referred to by Sjostrand were employed as early as 1943.

Wahlund (204) modified this test slightly when he tested 469 adult males on a Krogh bicycle ergometer starting at a work load of 300 or 600 kg-m/min. and increasing the work load by 300 kg-m/min. every 6 1/2 minutes until the subject could not continue or work at 1200 kg-m/min. was done. The pulse rate was determined at two minute intervals throughout the test. Lung ventilation, oxygen consumption and respiratory rates were determined at each work load. Wahlund concluded that it was possible to estimate the limit of cardiac output by studying the subject's pulse curve. He set the maximum heart rate at which work may be performed adequately at 170 beats per minute. If this heart rate is not reached he proposed that use be made of the known linear relationship between work load and heart rate to determine the work load which could be performed at that heart rate. That is, an extra or interpolation is made to the work load that could be performed at heart rate 170 (7). This is commonly called Physical Work Capacity 170, and is usually abbreviated at PWC_{170}. Wahlund also examined respiratory rate and established that it was less stable than pulse rate under work.

Wahlund concluded that the bicycle ergometer was a practical testing instrument and put forth a list of it's advantages. He also expressed the opinion that those factors which limit work capacity are neuro-muscular, circulatory-respiratory and psychological. For work continued to exhaustion, he felt that anaerobic work and mental stamina were being measured.

Other investigators, including Bengtsson (15), Adams *et al*. (1), Adams *et al*. (2), and de Vries and Klafs (53) have employed modified versions of the Sjostrand test in their studies. In recent years the Sjostrand test has been used in Canada. Cumming and Cumming (40) and Cumming and Young (42) followed the same procedure as Adams in the California study (2). In another study, Cumming and Danzinger followed a procedure similar to the second study by Adams (1). More recently, a modification of the Sjostrand test was employed by the Research Committee of the Canadian Association for Health, Physical Education and Recreation in studying the physical work capacity of 2107 Canadian children (7-17 years of age) and 910 adults (18-44 years of age) in 1967 (194) and 1971 (195), respectively. The test involved riding a bicycle ergometer for a total of twelve minutes, four minutes at each of three progressively heavier work loads. The Committee attempted to schedule the work loads for each subject so that the first work load produced a heart rate of 115-130 beats per minute, the second 130-145 beats per minute and the last 150-170 beats per minute. However, depending on deviations from the desired heart rate response at each work load, alterations in loading were made in levels two and three. The heart rate of the subject was monitored by an electrocardiograph at the end of each minute of exercise. The heart rate at the end of the fourth minute of each work load was plotted against the particular work load and a regression line drawn and extrapolated or interpolated to a heart rate of 170 beats per minute. The subject's score was the work he could produce at a steady heart rate of 170 beats per minute.

Advantages of this test were cited by the CAHPER Research Committee as being:

(a) the low cost of equipment and care of transporting it
(b) only a submaximal energy expenditure is required by subject
(c) simplicity of testing procedure
(d) high relationship with maximal oxygen intake tests
(e) criteria for tests measuring cardiovascular and pulmonary function are met: a large muscle mass in involved; the work increases in step-wise levels; each level is no longer than 6 minutes in duration and various parameters are easily measured during work on the bicycle ergometer.

Maximal Oxygen Intake, Body Weight and Various Components of Body Composition

It has been recognized for a long time that maximal oxygen intake is a function of body size. Many investigators have systematically related the observed values of maximal oxygen intake to body weight and various components of body composition (3, 6, 7, 44, 106, 139, 167, 168). In an early study, Johnston and Bernstein (94) found that as the percentage of weight in a heterogeneous group of women increased, the oxygen consumption remained equally well correlated with the surface area, lean body mass and cell mass (r = .91, .94 and .92 respectively). Bengtsson (15) indicated that body weight is a factor in the work capacity of children and young people up to the age of twenty. Miller and Blyth (137) reported that as body fat increases, exercise oxygen requirement per unit of lean body mass also increases, since fat is lifted as an inert weight. They pointed out that the work capacity of an obese person is limited, since the oxygen requirement per unit of lean body mass rises without a corresponding increase in the capacity for oxygen uptake.

Using 35 male and 35 female physical education students and staff ranging in age from 19 to 30 years, von Döbeln (203) determined body fat and maximal oxygen intake by water immersion densitometry and the Astrand and Rhyming nomogram (10), respectively. He found that no linear relationship existed between total body weight and maximal oxygen intake. Rather, the results showed a correlation coefficient of r = 0.75 between fat-free body weight and maximal oxygen intake, statistically significant at the .01 level of confidence. It was concluded that fat-free weight was the superior metabolic reference standard for the maximal oxygen intake. These findings were corroborated by Coyne (38).

Buskirk and Taylor (30) carried out a study similar to that of von Döbeln (203) using 46 healthy subjects who varied widely in terms of obesity and regular activity. The body composition measures were determined by the water immersion, densitometric technique, and the maximal oxygen intake was determined by treadmill running. The correlation coefficient between maximal oxygen intake and a) fat-free body weight, b) active tissue and c) body weight were found to be 0.85, 0.91 and 0.63 respectively. Upon dividing the sedentary students into three groups according to their relative obesity, it was shown that there was no difference in maximal oxygen intake per kilogram of fat-free weight in the three groups. It was concluded that when maximal oxygen intake is used to examine the capacity to perform exhausting work, the values should be expressed as oxygen per kilogram of body weight, but when the test is used to examine the performance of the respiratory-cardiovascular system, the values should be expressed as oxygen per kilogram of fat-free weight. It was also concluded that obesity per se has no effect on the maximal performance of the respiratory-cardiovascular system in young men.

A similar relationship was studied by Welch et al. (206) in 28 healthy young men. They concluded that the circulatory system seemed to be the major limiting factor in maximal oxygen consumption inasmuch as body weight, fat-free weight or fat-free weight minus bone weight accounted for only 35 percent, 41 percent and 41 percent respectively, of the variance in maximal oxygen intake. Also, whereas maximal oxygen consumption expressed in cc/min/kg body weight was significantly affected by percentage of body fat, maximal oxygen consumption expressed as 1/min. or cc/min/kg fat-free weight was not.

Other studies (1, 2, 13, 40, 53, 176) indicate a high correlation between physical work capacity and body weight, height and surface area, respectively.

It was shown by Keys _et al_. (100) that semi-starvation results in a decrease of maximal oxygen intake which is proportional to the body weight until a weight loss of 10 percent is reached. Somewhere between a 10 and a 17 percent loss of weight, the decline of maximal oxygen intake is markedly increased and there is a substantial loss in the capacity for anaerobic work.

In a study by White and Alexander (210) it was reported that the mean values for VO_2 (1/min) in obese subjects were considerably higher than those predicted at ideal weight, while the mean values of VO_2 per kilogram body weight were lower than those reported in normal subjects. Moody _et al_. (143) corroborated these findings, and further indicated that in their investigation $M\dot{V}O_2$ per kilogram fat-free body weight was approximately equal for both obese and lean women.

More recently, Dempsey et al. (50) stated that gross obesity in excess of 30% body fat imposes a severe decrement on physical work capacity, not only because of its presence as an inert non-contributory load, but also because of "...its apparent interference with overall-maximal cardiorespiratory function".

Twenty eight subjects ranging from 5.9 to 50.3% body fat were divided into four obesity groups. Differences among these groups with respect to physical characteristics were highly significant, with the exception of fat-free body weight. The maximal amount of oxygen available per kilogram of body weight decreased significantly as obesity increased from group to group. Various indices of work capacity were found to be related to body fatness in a negative fashion, especially evident by the control group's superiority over the obese of 200% in $\dot{V}O_{2max}$ per kg body weight and 145% in VO_{2max} per kg fat-free body weight.

In examining the effects of a 7 week program of dietary restriction and regular exercise on the aerobic capacity of seven 11 year old boys, Sprynarova and Parizkova (184) reported that prior to the program (when the ratio of adipose tissue in the body was higher), the relationship between $M\dot{V}O_2$ and lean body mass was less close than following the program, after reduction. A closer relationship existed between the $M\dot{V}O_2$ and lean body mass (p = 0.964) than with body weight (p = 0.929).

Skinner et al. (182) recently compared the working capacity of subjects of varying body composition divided into 4 groups: lean and active (LA), heavy and active (HA), lean and sedentary (LS) and heavy and sedentary (HS). The LA and HA showed no difference (.05 level) in maximal working capacity but they accomplished significantly more work than the LS subjects.

The Effect of Training on Maximal Oxygen Intake and Physical Work Capacity

It is generally conceded that better absorption and utilization of oxygen during rest and exercise is developed in the process of training (36, 59, 146). McNelly observed that:

> ...during exercise the quantity of oxygen absorbed per 100 cc of air breathed was greater for the trained than the untrained subjects. This is true in spite of the fact that during the preliminary rest period there is no significant difference between these figures for the trained and untrained subject (135).

Knehr et al. (104) found a decline in the mean oxygen requirement during grade walking on the treadmill of 1.91 to 1.78 l/min over a 6 month training period (middle distance running). Schneider and Crampton (175) studied the performance of athletes and non-athletes on the bicycle ergometer and concluded that approximately equal amounts of oxygen per square meter of body surface was consumed by both groups. Freedman et al. (67) concur where the work is submaximal. Studying cross-country athletes before and after training they observed that:

> No differences attributable to training were seen in the way a trained or untrained athlete meets the tissue demands for an increased supply of oxygen during exercise up to levels requiring about 2 liters of oxygen intake per minute.

Cooper (36), in comparing the effect of two types of training (short and intensive - 5BX and prolonged intensive - 13 station circuit training) on 30 male university students, reported that after 5 weeks of training both groups exhibited a lower oxygen intake during walking and running on a treadmill. Morehouse and Miller (146) point out that:

> If work is long-continued, the oxygen consumption of a trained subject remains constant throughout, whereas in untrained subjects the oxygen consumption is increased as exhaustion is approached.

More recently, Dempsey et al. (51) observed a decline in $\dot{V}O_2$ during moderate work of an obese subject following 5 weeks physical training. Other studies (57, 59, 60) have also reported a reduction in oxygen intake as a result of training.

It is generally agreed that maximal oxygen uptake (4, 49, 104, 140, 168, 169) and physical work capacity (60, 114, 150, 162, 183) can be increased with training. Many researchers have investigated the effect of training of varying types and intensities on the maximal oxygen uptake where subjects were normal, of different ages, convalescents or obese. Some of the authors include Buskirk and Taylor (30), Taylor et al. (193), Dempsey (50), Rowell et al. (173)

Sprynarova and Parizkova (184), Ekblom (60), Andersen (14), Fox et al. (49) Knowlton and Weber (105), Pollock, Cureton and Greninger (162), Ribsl (165) and Jetté and Thoden (90).

Dempsey (50) trained 18 men, 18 to 22 years old, for 18 weeks (daily training 8 weeks, decreased or normal activity 5 weeks, daily training 5 weeks). These men differed greatly in their degree of obesity prior to commencement of the training program which consisted of one hour sessions of "maximal movement" type exercise and individual and dual sports. The subjects were tested on 4 occasions (at the beginning and end of each phase) using the Balke treadmill test as the criterion of submaximal circulatory performance. Prior to the program, body fat (38.87%), fat-free body weight (9.72%) and relative body weight (1.72%) were each found to account for a significant portion of the total variance in treadmill performance. However, a decline in these relationships with training appeared to indicate that treadmill performance improved somewhat independently of changes in body composition or mass. That is, the greater improvement in cardiovascular variables was the major factor in the improved times.

Sprynarova and Parizkova (184) found as a result of a seven week program of dietary restriction and regular exercise for seven 11 1/2 year old obese boys, that marked changes in body composition (a decrease in body weight due adipose tissue decrease and concomitant increase of lean body mass) resulted in a decrease of $\dot{V}O_{2max}$ in absolute values. The rise of $\dot{V}O_{2max}$ per kilogram body weight and the drop of $\dot{V}O_{2max}$ per kilogram lean body mass were not significant. In comparing changes in aerobic capacity and body composition as a result of training, the authors correlated the decrease of absolute values of $\dot{V}O_{2max}$,the rise of $\dot{V}O_{2max}$ per kilogram body weight and the decrease of $M\dot{V}O_2$ per kilogram LBM. Between the decrease of LBM and the drop of $\dot{V}O_{2max}$ a significant negative relationship ($p = -0.848$) was found, while between the decrease of LBM and the rise of $\dot{V}O_{2max}$ per kilogram body weight, a significant positive relationship ($p = 0.848$). More recently, Knowlton and Weber (105) observed that a 10 week physical training program resulted in a + 22% improvement in $\dot{V}O_{2max}$ expressed in cc/kg/min for 18 obese subjects as predicted from both submaximal and maximal exertion tests. No interaction (using regression analysis) between predicted $\dot{V}O_{2max}$ and mean recovery heart rate with body weight was noted, thus indicating the main effect to result from training, rather than weight reduction.

Holmgren _et al_. (83) compared the effects of intermittent long-term training (gym exercises, running one or two times per week for several months) versus continuous short-term training (daily skiing for eight to ten days) in 87 normal subjects. The latter type of training increased PWC_{170} more than the former type, an effect indicated to be dependent upon the intensity rather than the daily duration of training. Adams et al. (1) found the working capacity of 10 to 12 year old Swedish children from both city and country to be significantly greater with an increasing degree of physical training. Ekblom (60) attributes a 10% elevation in aerobic capacity (from 3.1 to 3.4 l/min) in 8 male subjects following 4 months training (cross-country running) to an increased cardiac output in addition to an increased extraction of oxygen from the blood. However, Ekblom commented that "...the work capacity does improve more during training than reflected in the increase of aerobic work capacity".

The Effects of Physical Activity on Body Weight and Body Composition

One of the prominent factors influencing an individual's whole body composition is his intensity of physical activity. It was Behnke et al. (16) who found that players of American Football, all physically very fit, would have been classified as "overweight" and thus unfit to serve in the Navy. The high specific gravity of these football players indicated that their bodies contained a small amount of adipose tissue but a greatly developed muscle mass. Thus, the fundamental finding of the marked difference in body composition of trained and non-trained individuals was established. Brozek (22) reviewed an early study by Behnke and Taylor in which the mean body densities of five athletes, mainly weight lifters, and less than 30 years of age, were found to be much higher than the mean for non-athletes of corresponding age. Moreover, athletes taking part in basketball, football and ice hockey training programs (43, 197, 198) showed decreasesin skinfold measurements and increases in body density, thus indicating a loss of body fat which has a lower density than muscle. Total body weight did not change significantly in any of the above studies.

Keys and Brozek (101) carried out extensive examinations of male populations engaged in occupations involving muscular work of different intensity. By comparing "active" and "sedentary" occupations, these investigators found that men performing physical work tend to have, even when their relative body weight is equal, less fat in their organism than men of the sedentary group. When attention was focused on men who fell into the upper third of the distributions of relative weight and skinfolds, among "active" men there was a relative predominance of subjects who were heavy but not fat, while the more sedentary individuals were fairly frequently classified as fat without being heavy.

Many investigators have reported the effects of training programs of varying types, lengths and intensities on the body weight and composition of human subjects. A number of these studies are summarized in Table 1. It should be noted that the symbols -, + and NC denote a loss

Table 1

The Effects of Physical Activity on Body Weight and Body Composition

Investigator & Ref. No.	Year	Classification of Subjects	No.	Age	Physical Activity (Span)	Body Weight	Components of Body Composition
Cureton (44)	1947	Self	1	43	running & swimming for endurance (3 mos.)	-	total body fat -; girths- (calf, thigh, gluteal, biceps)
Cureton (45)	1947	Firemen	15	not stated	calisthenics (6 mos.)		fat -
Kireilis & Cureton (103)	1947	Fat PE Students	3	not stated	running (6 wks)	slight	external fat -
Cureton (1946)	1952	Professor	1	59	walking & calisthenics (6 mos.)	-	over-all fat-, abd. fat-, waist fat-, fr. thigh fat-; girths (abd-, deflated chest +, expanded chest +, calf +)
Brodt (Cureton (43))	1950	not stated	6	not stated	wt. lifting (18 wks)		fat NC
Herkimer (Cureton (43)	1949	Adult Males	12	not stated	calisthenics, VB, individual exercises (7 mos.)	wt. residuals -	total body fat -

Table 1 (continued)

Investigator & Ref. No.	Year	Classification of Subjects	No.	Age	Physical Activity (Span)	Body Weight	Components of Body Composition
Hopkins (Cureton (43))	1951	Adult Males	16	26-54	calisthenics, VB (6 mos.)		total body fat NC
Kristufek (Cureton (43))	1951	Adult Male	1	22	running 3 mi/ day for 49 days	wt. residuals NC	total body fat -
Nakamura (Cureton (43))	1951	Adult Male	1	21	sprint swimming (10 wks)		total body fat -; chest girth +
Wolbers (Cureton (43)	1949	Adult Males	9	28-50	VB (26 weeks)	wt. residuals NC	total body fat NC
Wolfson (Cureton (43))	1950	Adult Males	9	20-60	prescribed exercises	wt. residual (tissue density)+	total body fat -
Brozek (23)	1952	Inactive vs Active Business & Professional Men	56	52	Active: Recreational Activities; Inactive-Sedentary (Adulthood)	active heavier	fat less in active; greater FFBW in active; greater SG in active

Table 1 (continued)

Investigator & Ref. No.	Year	Classification of Subjects	No.	Age	Physical Activity (Span)	Body Weight	Components of Body Composition
Thompson et al. (198)	1958	Varsity + Freshman BB Players; Hockey Players	26	21	BB; Hockey (1 season)	NC	subcutaneous fat (chest -, abd. -, upper arm -); muscle mass +; body density +
Thompson (197)	1959	Varsity FB Players	34	20	Football (1 season)	NC	subcutaneous fat (chest -, abd. -, upper arm - ; muscle mass +; body density +
Stefanik et al. (185)	1961	PE & Physical Therapy Female College Students	58	18	PE program (8 mos.) & Camp-sports & skills (4 wks)	NC	subcutaneous fat - (scapular, abdominal)
Roby (170)	1962	Male Students	15	21	wt. training of dominant arm triceps (10 wks)		no regional reduction of subcutaneous fat over triceps
Schade et al. (174)	1962	Overweight College Women	22	17-21	grp.I. general body exercises (6 wks) grp. II. spot exercises on hips & abdomen (6 wks)	I.& II. slight-	II. fat - over hips & abdomen

Table 1 (continued)

Investigator & Ref. No.	Year	Classification of Subjects	No.	Age	Physical Activity (Span)	Body Weight	Components of Body Composition
Wells *et al.* (174)	1963	Adolescent High School Females	34	not stated	calisthenics, gymnastics, wt. lifting, dancing, games, tr. & field, swimming daily (5 mos.)	NC	excess body fat-; active body tissue+
Jokl (95)	1945	Adolescent Male	1	15	intensive training daily (10 mos.)	-	muscle mass +
Dempsey (50)	1964	Obese Young Men	7	18-28	daily training (8 wks); decreased or normal activity (5 wks) and daily training (5 wks)	-	total body and subcutaneous fat-; FFBW$^+$; muscle mass+
Skinner *et al.* (181)	1964	Professional Men	15	35-55	calisthenics, running (6 wks)	NC	subcutaneous fat-; girths - (abd., chest, gluteal); SG$^+$

Table 1 (continued)

Investigator & Ref. No.	Year	Classification of Subjects	No.	Age	Physical Activity (Span)	Body Weight	Components of Body Composition
Cureton & Phillips (48)	1964	Adult Males	6	28-47	calistenics, X-country running, squash (8 wks) rest-off (8 wks); then as first 8 wks (8 wks)	-	total body fat-; abdominal girth -
Mohr (141)	1964	College and Older Women	30	18-45	daily isometric abdominal exercises (4 wks)		subcutaneous fat - (waistline, abd.); girths - (abd., waistline)
Sprynarova & Parizkova (184)	1965	Obese Boys	7	11^1/2	recreational therapeutic camp and dietary restriction (7 wks)	-	adipose tissue fat-; LBM-
Garrett *et al.* (70)	1965	Adult Males	13	21-40	not stated (6 wks)	-	
Christakis *et al.* (34)	1966	Obese High School Students	55	13-14	PE classes, body building exs., wt. lifting and general conditioning exs., BB (18 mos.)	+ less than a control group	

Table 1 (continued)

Investigator & Ref. No.	Year	Classification of Subjects	No.	Age	Physical Activity (Span)	Body Weight	Components of Body Composition
Métivier (136)	1966	Adult Men	33	19-32	3 games hockey/ wk. (2 1/2 mos.)	slight	subcutaneous fat - (triceps, scapula, calf, hip, abd.)
Oscai & Williams (153)	1968	Overweight Males	5	35-46	running (16 wks)	-	total body fat -; FFBW NC
Jetté (89)	1969	Adult Males	27	35-72	Habitual exercisers (run, jog, swim 3 hr/ week or more (8.5 yrs)	-	girths - (abd; gluteal)
Pollock et al. (162)	1969	Adult Males	not stated	28-39	I. 2 days/ wk. II. 4 days/wk. training (20 wks)	I. NC II. -	I. fat NC, % body fat-; I. FFBW NC, II. FFBW +
Elder (61)	1969	Adult Males	83 (average)	23 1/2 - 72 1/2	rhythmical exs. and jogging 3 days/wk. (3 mos.)		adipose tissue fat-
Knowlton & Weber (105)	1969	Markedly Obese	18	not stated	progressive training (10 wks).	-	body fat (%) - (chest, biceps-, abd. +); girths - (chest, abd., upper arm, calf)

or decrease, a gain or increase and no change, respectively, in the components of body composition cited.

Keys (98) also analyzed body weight and composition changes as a result of vigorous muscular exercise. The major changes involve a decrease in fat and an increase in muscle mass with the variations in total body weight dependent upon the proportional change in these two components, which in turn are determined by the type of "training" employed.

Parizkova (154) of Czechoslovakia has reviewed some European studies investigating the influence of physical activity on body composition. For example, Khanina and Chagovets studied a group of students at the Kiev Institute of Physical Training (USSR) during one year of intensive physical training. They found that during the period body weight, as well as specific gravity, increased. Parizkova's own studies (154) reveal a higher density (i.e. a higher fraction of lean body mass) in physically active individuals (children, adults and the elderly). The greatest differences were observed in top athletes over 20 years of age in whom the intensity of exercise was greatest. Her investigations on male and female members of the Czech national gymnastic team before and after intense training for the Olympic Games, and after a period of rest revealed that following intense training the body weight remained practically unaltered while sport performance increased and the amount of total body fat and subcutaneous fat declined, as shown by measurements of body density and skinfold thickness. After discontinuation of training, the body weight tended to increase as a result of deposition of adipose tissue. It was concluded from changes in body density which declined that a relative (and at times, perhaps an absolute) reduction of LBM and concurrent deposition of adipose tissue must have occurred, a trend similar in both sexes.

Pitts (160),in maintaining male guinea pigs on a severe exercise regime from the time of weaning until they were 8 months old, found that they differed in body composition, in the predictable direction, from the nonexercised adult series. They were slightly lighter (603vs 708g), the specific gravity of the eviscerated carcass was substantially higher (1.073 vs 1.057) and the total extractable fat, expressed as a percentage of fat-free body weight, was lower (11.7 vs 20.7 %). Thomas and Miller (196) while investigating the response of rats to a gradually increasing load of treadmill exercise for three or five days a week, observed that initially there was a decrease in food intake, weight gain and spontaneous activity on the days of exercise and a compensatory increase in food intake and weight gain on rest days. Jones _et al_. (96) found that growing rats subjected to a program of swimming gained weight more slowly and had a lower body fat content than sedentary controls. Parizkova and Stankova (155) forced rats to run about 1 km/day for about 200 days and although the animals adapted fairly well, they fell some 20 gm behind the controls when exercise was begun, an initial deficit of body weight that subsequently was never recovered. At the end of the experiment, their content of body fat was less than that of controls. These findings corroborate those of Larsson (111), Hanson (78) and Crews _et al_. (39) where exercised rats exhibited a decrease in fat content in the body (plus a relative increase in LBM (Crews)) with or without a concurrent weight change of the body.

A number of investigators have been interested mainly in the effect of exercise on girth and subcutaneous fat reduction. Kireilis and Cureton (103) found fat loss, after six weeks of strenuous running, to be greater on the hips, gluteals and rear thigh than on the abdomen, chest and front thigh. Thompson _et al_. (198) and Thompson (197) obtained significant changes in skinfold measurements at the abdomen, chest and upper arm with football, basketball and hockey players after a season of athletic participation. On the other hand, Roby (170) failed to observe any significant loss of subcutaneous fat in the area of the triceps following a 10-week weight training program. Schade _et al._ (174) using photographic means of assessing fat distribution, observed fat and weight losses in each group of subjects using sport and generalized exercise, respectively, but no greater differences in the group using localized exercises for hip and abdoman reduction. More recently, Mohr (141) reported significant reductions in girth and subcutaneous fat at the waistline and the umbilical level of the abdomen in 30 women following a regime of six isometric abdominal contractions daily for 4 weeks. There was no appreciable weight change noted. Other researchers have been concerned about fat changes concurrent with weight loss. Measuring college freshman women in early fall and late spring, Stefanik et al. (185) observed that when weight loss occurred this was accompanied by loss in scapular and abdominal skinfold thickness, but not in the arms. Garn and Brozek (69) found that during weight loss, fat was withdrawn in proportion to the initial amount present; the thickest deposits sustained the greatest loss during caloric restrictions.

Dempsey (50) reported that initially overweight male subjects (18 to 28 years of age), as a result of 18 consecutive weeks of daily training (8 weeks), normal activity (5 weeks) and daily training (5 weeks), showed significant losses of body weight, subcutaneous and total body fat, and increases in fat-free body weight and muscular mass. Fat-free body weight also showed some relation to the amount of excess fat being carried. Parizkova (154) and coworkers investigated for four years changes in body composition in a group of 60 to 70 obese girls and boys subjected to reducing treatment in special vacation camps; weight reduction occurred as a result of 1700 calorie diet in conjunction with a program of intense physical training.

After six to seven weeks, every child had lost weight (an average of 10% of initial weight) due to reduction of fat by changes in body density and skinfold thicknesses. Similar changes, in other words reduction of fat after physical exercises in children, are reported by Wells et al. (207, 208). Parizkova (154) observed that:

> ...obese children of different ages do not respond to the reducing regimen in an equal manner. In children near the onset of the prepubertal growth acceleration fat is reduced but - to a smaller extent - the lean body mass is also affected. It seems that during this period children are particularly sensitive to sudden and marked changes in the energy balance. In somewhat older children who have already passed the period of maximum growth acceleration, this phenomenon is not found under equal conditions.

A further study of obese girls and boys was carried out for two years. Changes in the density showed that increase in weight in these growing children was due not solely to an accumulation of fat but also to a large development of lean body mass, accounting on the average for 60 percent of the weight increment. A second holiday camp in which the selected group of children participated resulted in further reduction of fat content, and body density of these children approached more closely values found in corresponding normal individuals. The amount of subcutaneous fat in the boys and in the girls changed similarly. More recently, Sprynarova and Parizkova (184) found decreases in body weight as a result of reduction of adipose tissue and lean body mass in seven 11 year old obese boys who underwent a program of regular exercise and dietary restriction for seven weeks. The ratio of LBM to body weight also increased.

Christakis et al. (34) examined a group of male obese adolescents following a combined nutrition education and physical fitness program. The experimental group gained a smaller amount of weight (5.8 lbs vs 13.5 lbs) compared to that among the control group, resulting in an 11% decrease in average degree of overweight in the experimental group compared to a 2% decrease in the control group.

Malina (119) in 1969 reviewed and criticized current concepts on exercise as an influence upon growth. Based on the studies reviewed and his own discussion, the following conclusions were brought forth:

1. Changes produced in the body by short-term physical exercise programs are not permanent, but depend upon the continuation of activity for their maintenance. In body composition studies and in specific training programs that cause muscular hypertrophy, this is particularly true. Further study is required to determine how much and what type, frequency or duration of activity is necessary to maintain those changes brought about by exercise. Permanent specializations and training however, lead to more chronic changes associated with exercise, particularly

increases in lengths of the involved long bones.

2. Variables seemingly related to permanent changes resulting from exercise programs, especially in growing children, appear to depend upon factors such as ages of the subjects, general physical condition at the beginning of the exercise program, body build and type and duration of physical exercise (since training effects are generally rather specific).

3. Some researchers propose that there are critical periods during which the growing body or a part of the body is most sensitive to the growth-stimulating effects of exercise programs. However, when such periods occur, if they exist at all, has yet to be determined.
4. A certain minimum of physical exercise appears necessary to support normal human growth and to maintain the integrity of osseous and muscular tissues. What this minimum is or should be and what effects more extended exercise programs may have, has yet to be determined also.

Metabolic Cost of Exercise in the Obese

As early as 1929, Newburg and Johnston (151), based on a study by Lauter, stated that the obese person uses more energy to perform a given piece of work than a normal person. Mahadeva et al. (117) in studying the metabolic cost of standardized stepping and walking in 50 subjects, reported that in any activity in which a large proportion of energy expenditure is used to move the body weight, the metabolic cost is directly proportional to the body weight. Subsequent investigations (58, 118, 120, 134, 138, 158, 161) support this position.

Mayer (120) comments that if excess body weight is so great that it impairs muscular efficiency, the cost of exercise may be proportional to a power of body weight greater than unity. The obese subject will require more energy and hence burn up more body fat for the same amount of exercise than a normal subject.

Miller and Blyth (137) have examined the influences of body type and body fat content on the metabolic cost of work using 30 active male college students. They concluded that:

1. The metabolic cost of lifting the body is directly proportional to gross body weight, and the cost of work per unit of body weight is only slightly influenced by height and fat content.
2. The correlations between metabolic work cost and height, lean body mass, chest circumference and abdominal circumference are reduced to

insignificance if the influence of weight is eliminated. But, the correlation between metabolic work cost and weight remains highly significant when the separate influences of height, fat content and lean body mass are eliminated. Gross body weight is the best metabolic reference unit for expressing the cost of work involving lifting the body weight.

3. As body fat content increases, the exercise O_2 requirement per unit of lean body mass also increases. Obesity limits the capacity for strenuous exertion by increasing the energy cost of exercise without a proportional increase in maximal capacity for oxygen uptake.

Other investigators (17, 29) are in agreement that obesity increases the energy cost of exercise.

Bloom and Eidex (17) found that an obese person tolerates his weight better than a lean person carrying a load to give him a total weight equal to that of the obese. Although aforementioned studies indicate that the energy required to lift and move the body weight is linearly related to the magnitude of the mass being moved, observations on subjects of both sexes varying greatly in body weight and age (9, 152, 204) have shown this relationship does not hold true for work on the bicycle ergometer; "The mechanical efficiency on the bicycle ergometer is relatively constant and since the subject does not carry his own weight while exercising, $\dot{V}O_2$ (per unit of work output) is independent of body weight" (152). Dempsey (51), however, commented that in the grossly obese individual, muscular work and the energy expenditure on the bicycle ergometer may not be entirely independent of body mass.

Cholesterol

Normal Values. Normal cholesterol values as stated by the NIH Centre (144) are listed in Table 2. As evident from the table, cholesterol values increase with age.

Cholesterol and Obesity. Kritchevsky (109) has reviewed early studies relating body build to serum cholesterol. These studies revealed a higher serum cholesterol in stocky built persons than slender ones. Tanner (190) compared the relationship between somatotype and serum cholesterol level and found a significant correlation with endomorphy, a nearly significant one with ectomorphy and none with mesomorphy. Gertler *et al.'s* (71) data concerning cholesterol levels of normal and coronary patients as related to somatotype are presented in Table 3.

More recently, cholesterol has been implicated in the development of atherosclerosis. A correlation between the two appears definite based on studies but the extent of this relationship is the controversial issue (72, 102, 110, 215).

Table 2

Normal Cholesterol Levels (NIH Clinical Centre)

Age	Total Cholesterol (mg/100ml plasma)
1-19	120-130
20-29	120-240
30-39	140-270
40-49	150-310
50-59	160-330

Table 3

Serum Cholesterol (mg%) and Somatotype*

Somatotype	Cholesterol Control	Level Coronary
Endomorph	235	287
Mesomorph	223	294
Ectomorph	208	265
Middle	227	279

* After Gertler, Garn and Sprague (71)

The most significant factor indicating a relationship between cholesterol and atherosclerosis is that this sterol is always prominent in atherosclerotic plaques. Although many studies support the theory that high blood cholesterol levels lead to atherosclerosis, a few indicate the contrary (212).

Notwithstanding, the evidence that obesity is related to atherosclerosis and consequently high cholesterol levels presents conflicting evidence. Dock et al. (54) have commented that although obesity may predispose to atherosclerosis, it plays no part in causing coronary disease in men under 45 years old. Rather, the avoidance of obesity was recommended as an effective prophylaxis to atherosclerosis.

Lewis et al. (113) reported higher cholesterol levels in overweight groups than in normal groups. Keys (99) found in healthy men of the same age classified according to relative body weight as percent of standard average for height and age serum cholesterol values (mg/100 ml) of 222.7 ± 4.7, 228.0 ± 5.9 and 225.1 ± 6.6 for less than 95%, 95 to 105% and more than 105% relative weight, respectively. Roberts (166) stated that autopsies on 47 obese males indicated more coronary atherosclerosis than autopsies of 47 thin males. 30 obese females had more atherosclerosis in every site than 30 thin females, and also more atherosclerotic calamaties. Livas (115) similarly observed that in blood cholesterol investigated in 130 patients, 85 men and 45 women with atherosclerosis, obesity was present in more than half of the cases.

The Effects of Chronic Exercise and Physical Training on Cholesterol. The influence of chronic exercise and physical training on serum lipids, especially cholesterol, is not definitely established. Evidence indicates conflicting results regarding the reduction of serum cholesterol in humans as a result of exercise. Some studies report a decrease (31, 55, 70, 73, 136, 142, 148, 149, 162, 171), while others no change (31, 82, 93, 97, 192). Most of the controversy appears to revolve around adequate dietary control and varied intensities of training regimens. Diet, total calories, and the ratio of fat intake to total calories have a marked effect upon serum lipid concentration; thus strict dietary records are necessary for a clearer interpretation of training effects.

In animals it has been shown that physical training lowered serum cholesterol levels of cockerels (205, 214), but caused no alteration in rats (65) and mice (63, 96). Myasnikov (147) was able to show that blood cholesterol levels of rabbits fed cholesterol and exercised daily for 6 months on a treadmill, to be lower than those fed cholesterol only. These findings corroborate those reported by Kobernick et al. (107). Brown et al. (21) also reported a reduction in serum cholesterol by exercising cholesterol-fed rabbits daily. When mice made obese by gold thioglucose injection or heredity were exercised, their serum cholesterol levels did not differ from those of rested controls, but control, non-obese littermates exhibited drops in serum cholesterol levels (131).

Cureton (47) has recently reviewed the studies pertaining to cholesterol conducted at his laboratory. The data from some ten studies show that only those programs of the continuous nonstop rhythmical type (endurance programs such as running, swimming, skating, skiing, cycling, hiking and competitive games) in which weight is lost and a negative caloric state results are effective in reducing cholesterol. In order to achieve a significant reduction, Cureton has recommended, based on studies, a one hour daily workout, 5 to 6 days a week, or three or more longer workouts of 1 1/2 to 3 hours every other day. He points out that many studies indicate that the intensity or rate of work is as important as the length of the workout. A reduction in cholesterol is not specific but is related to all of the metabolic and fitness changes brought about by training.

Thyroxine (T_4)

Concept. The thyroid gland secretes a number of hormones - most abundantly thyroxine and smaller amounts of closely iodinated hormones (triiodothyronine, diiodothyronine etc). Iodides ingested orally are absorbed from the gastrointestinal tract into the blood. Within the first 3 days, two-thirds of the ingested iodides are normally lost into the urine and the remaining one-third is selectively removed from the circulating blood by cells of the thyroid gland and used for synthesis of thyroid hormones, which are either stored in the form of thyroglobulin in the follicles or secreted into the blood principally in the form of thyroxine (76). Within the plasma, thyroxine is transported almost entirely in association with two proteins, the so-called thyroxine-binding proteins (thyroxine-binding globulin, TBG and thyroxine-binding prealbumin, TBPA) which act as specific carrier agents for the hormone (75). As the thyroid hormones circulate through tissues, they are freed from protein carriers, pass through capillary walls and impinge upon the tissue cells (199).

The total circulating thyroid hormone is measured as the so-called protein-bound iodine (PBI). In euthyroid individuals, its concentration is between 4 and 8 µg/100ml (79). The normal range for serum thyroxine iodine, as found in this study, is 2.8 to 6.4 µg/100ml (156). Knowledge of thyroid metabolism was advanced by applying techniques of chromatography and radioautography of compounds labelled with I^{131}(200).

The functions of thyroxine in the tissues are many (75). Those more relevent to this study may be summarized as:

a) general increase in metabolic rate of many body tissues. The BMR can increase to as much as 60 to 100 percent above normal when large quantities of thyroxine are secreted. The rate of utilization of foods for energy is greatly accelerated. The effect of thyroxine on cells is to increase quantities of certain intracellular enzymes, which in turn increases the overall metabolism of the cell, including increased utilization of oxygen, glucose, fats and proteins.

b) effect on carbohydrate metabolism, fat metabolism, protein metabolism and growth.

Thyroxine Metabolism in Obese Adolescents. The question of hypothyroidism as a cause of obesity in adolescents is frequently raised (86). Kupperman (108) states "There is no specific pattern of obesity noted in hypothyroidism, nor does hypothyroidism per se appear to play a major role in obesity". Usually, a low BMR is put forth as the reason for treating the obese person with thyroid hormone. Heald (80), however, states that the BMR is totally unreliable in obese adolescents and should not be used as a criterion for the diagnosis of hypothyroidism in this age group. Notwithstanding studies (108) in obese adults have failed to reveal any abnormality of thyroid function as measured by serum levels of protein-bound iodine (211) or 24-hour thyroidal uptake of radioactive iodine (86). Similarly, a recent study by Hung et al. (86) failed to detect any difference in the rate of thyroxine utilization in obese adolescent males. 9 obese euthyroid adolescent boys, ranging from 12 to 16 years were studied at two stages of sexual maturation. The mean half-life for thyroxine in stage 3 (period of intense and rapid growth) and stage 5 (end of adolescent spurt) obese boys was not significantly different from the counterpart in non-obese boys.

The Effects of Acute and Chronic Exercise on Thyroxine Metabolism. A number of writers (18, 19, 52, 87, 88, 112, 163, 164, 202, 213) have investigated the quantitative relationship between thyroid activity and muscular activity. Bogoroch and Timiras (18) studied the effect of forced muscular exercise on the uptake of ^{131}I by the thyroid gland of rats and found that in one group there was no significant change, while in a second group there was a significant depression. While Bondy and Hagewood (19) found that in rats two hours swimming caused a pronounced fall in protein-bound iodine, in a later report from the same laboratory, Lashof et al. (112) commented that the low temperature of the water rather than the muscular activity may have been enough to account for the fall in PBI. They subjected one group of 6 subjects, 20 to 26 years, to moderate exercise (14 miles of walking) and another group of 6 to severe brief exercise (swimming maximally for 6 minutes). No change in the peripheral utilization of thyroid hormone (as noted from the concentration of circulating hormone and by the rate of disappearance of injected radiothyroxine) occurred. The authors commented that a lack of change perhaps indicated that a much more prolonged change in the metabolic needs of the body were required in order to alter thyroid function.

Escobar del Rey and Morreale del Escobar, as reported by Irvine (88) found that, three hours after thyroxine ^{131}I, resting rats had a significantly lower plasma PB^{131}I than those which swam vigorously for most of the period. On the other hand, when slaughtered at the end of 24 hours, resting rats had a significantly higher plasma PB^{131}I than rats which ran for nine of the 24 hours. Other evidence suggests that muscular activity has no relationship (112, 202, 213) or an inverse relationship (18, 163) to thyroid activity. Two studies from the former supposition are those of Volpé et al. (202) and Wilson (213). Volpé et al. studied the effect of the physical stress of professional football contests in 6 players through a series of 3 games, and a fourth player for 1 game only. They found no fluctuation of the protein-bound iodine level beyond that found in normal healthy persons. Wilson found an increase of 20% in BMR in man after 5 weeks of athletic training and moderately heavy manual work. However, he concluded that there was no change in thyroid activity because there was (a)no change in ^{131}I uptake or urinary excretion and (b) no change in PBI and uptake of tri-iodothyroxine by erythrocytes. He did find a 4 to 5 fold increase in the 4 to 8 hour PB^{131}I after the training period which Irvine (87) suggests may have been due to increased thyroidal turnover.

Rhodes (164), finding twice as much total thyroidal iodine in non-exercising rats as compared to exercised rats, concluded that the more rats exercise the less the storage of iodine in the thyroid gland. He felt that the utilization of thyroid hormone is increased so that more dietary hormone is converted to circulating hormonal iodine and less to stored iodine, based on the premise that decreased or absence of thyroxine is associated with a decreased utilization of oxygen and decreased energy exchange in respiring tissues. In a group of horses, Irvine (87) found that, after 3 months of physical training, the thyroxine secretion rate had increased to 165%, PBI had decreased 39% and the fractional turnover of thyroxine had increased to 262% of pre-training values.

De Nayer et al. (52) studying 11 trained male athletes during the Harvard step test, reported that a slightly significant decrease in PBI and a statistically significant lower value for circulating free thyroxine level were observed after exercise. They suggested that this was due to an increased cellular utilization of thyroxine. Similarly, Irvine (88) found that when non-athletic young men commenced taking daily muscular exercise (running) peripheral degradation of thyroxine increased after a latent period, reaching 40% above resting level after 6 days. Athletes in moderately severe training had a thyroxine degradation/secretion rate 75% above that of resting non-athletes, due to increased fractional turnover with little change in pool size. This fell significantly after 3 days of rest. PBI and free thyroxine levels were not significantly changed, the non-significant 17% increase in free thyroxine level being primarily due, the author states, to increased peripheral deiodination of thyroxine and in turn believed to be due to repeated muscular exercise per se. Irvine (88) has criticized the conclusions of some previous investigators (18, 19, 112, 213) saying that their failure to obtain an effect on thyroid function due to muscular exercise was a result of the inadequacy of the exercise and the insensitivity of the method.

REFERENCES

Chapter II

1. F.H. Adams, E. Bengtsson, H. Berven and C. Wegelius, "The Physical Working Capacity of Normal School Children. II. Swedish City and Country," *Pediatrics*, 28: 243-257, 1961.

2. F.H. Adams, L.M. Linde and H. Miyaka, "The Physical Working Capacity of Normal School Children in California," *Pediatrics*, 28: 55-64, 1961.

3. B. Ahlborg, G. Ahlborg, M. Aurell and K. Linroth, "Capacity for Brief Exercise in Relation to Capacity for Prolonged Exercise in Man," *Acta Medicina Scandinavica, Försvarsmedicin*, 3, *Supplement 1: 151, 1967.*

4. K.L. Andersen, "Measurements of Work Capacity, "*Journal of Sports Medicine and Physical Fitness*, 4: 236-240, 1964.

5. K.L. Andersen and M. Kai, Chairmen, *Committee on Physiological Measurements and Indices*.

6. K.L. Andersen, R.J. Shephard, H. Denolin, E. Varnauskas and R. Masironi, *Fundamentals of Exercise Testing* (Geneva: World Health Organization, 1971).

7. P.-O. Astrand, "Direct and Indirect Determination of the Maximal Oxygen Uptake," *Acta Medica Scandinavica, Försvarsmedicin*, 3: 145-150, 1967.

8. P.-O. Astrand, *Experimental Studies of Physical Working Capacity in Relation to Sex and Age* (Copenhagen: Munksgaard, 1952).

9. P.-O. Astrand, "Human Physical Fitness with Special Reference to Sex and Age," *Physiological Reviews*, 36: 307-335, 1956.

10. P.-O. Astrand and I. Rhyming, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate during Submaximal Work," *Journal of Applied Physiology*, 7: 218-221, 1954.

11. P.-O. Astrand, I. Astrand, E. Christensen and R. Hedman, "Circulatory and Respiratory Adaptation to Severe Muscular Work," *Acta Physiologica Scandinavica*, 50: 254-258, 1960.

12. B. Balke and R.W. Ware, "The Present Status of Physical Fitness in the Air Force," USAF School of Aviation Medicine, 59-67: 1-9, 1959.

13. G.H. Baycroft, "An Evaluation of the Modified Astrand-Rhyming Nomogram as an Estimator of Maximal Oxygen Consumption," (unpublished M.Sc. thesis, University of Alberta, 1964).

14. R. Beaudoin and J. Mayer, "Food Intakes of Obese and Non-Obese Women," Journal of the American Dietetic Association, 29: 29-33, 1953.

15. E. Bengtsson, "The Working Capacity in Normal Children Evaluated by Submaximal Exercise on the Bicycle Ergometer and Compared with Adults," Acta Medica Scandinavica, 154: 91-109, 1956.

16. A.R. Behnke, B.G. Feen and W.C. Welham, "The Specific Gravity of Healthy Men," Journal of the American Medical Association, 118: 495-497, 1942.

17. W.L. Bloom and M.F. Eidex "The Comparison of Energy Expenditure in the Obese and Lean," Metabolism, 16: 685-692, 1967.

18. R. Bogoroch and P. Timiras "The Response of the Thyroid Gland of the Rat to Severe Stress," Endocrinology, 49: 548-556, 1951.

19. P.K. Bondy and M.A. Hagewood "Effect of Stress and Cortisone on Plasma PBI and Thyroxine Metabolism in Rats," Proceedings of the Society for Experimental Biology and Medicine, 81: 328-331, 1952.

20. I.P. Bronstein, S. Wexler, A.W. Brown and A.J. Halpern, "Obesity in Childhood. Psychologic Studies," American Journal of Disabled Children, 63: 238-251, 1942.

21. C.E. Brown, T.C. Huang, E.L. Bortz and C.M. McCoy, "Observations on Blood Vessels and Exercise," Journal of Gerontology, 11: 292-297, 1956.

22. J. Brozek, "Research on Body Composition and its Relevance for Human Biology," Human Biology, J. Brozek, editor (London: Permagon Press, 1965), pp. 89-119.

23. J. Brozek, "Changes of Body Composition in Man during Maturity and their Nutritional Implications," Federation Proceedings, 11: 784-793, 1952.

24. H. Bruch, "Physiological and Psychological Aspects of Food Intake of Obese Children," Americal Journal of Disabled Children, 59: 739-781, 1940.

25. H. Bruch, "Obesity in Childhood. IV. Energy Expenditure of Obese Children," American Journal of Disabled Children, 60: 1082-1109, 1940.

26. A.M. Bryans, "Childhood Obesity - Prelude to Adult Obesity," Canadian Journal of Public Health, 58: 486-490, 1967.

27. B.A. Bullen, L.F. Monello, H. Cohen and J. Mayer, "Attitudes Toward Physical Activity, Food and Family in Obese and Nonobese Adolescent Girls," American Journal of Clinical Nutrition, 12: 1-11, 1963.

28. B.A. Bullen, R.B. Reed and J. Mayer, "Physical Activity of Obese and Nonobese Adolescent Girls Appraised by Motion Picture Sampling," American Journal of Clinical Nutrition, 14: 211-223, 1964.

29. E.R. Buskirk, "Problems Related to the Caloric Cost of Living," Bulletin of the New York Academy of Medicine, 36: 365-388, 1960.

30. E. Buskirk and H.L. Taylor, "Maximal Oxygen Intake and its Relation to Body Composition, with Special Reference to Chronic Physical Activity and Obesity," Journal of Applied Physiology, 11: 72-78, 1957.

31. D.E. Campbell, "Influence of Several Physical Activities on Serum Cholesterol Concentrations in Young Men," Journal of Lipid Research, 6: 478-480, 1965.

32. H. Canning and J. Mayer "Obesity: Analysis of Attitudes and Knowledge of Weight Control in Girls," Research Quarterly, 39: 894-899, 1968.

33. A. Chirico and A.J. Stunkard, "Physical Activity and Human Obesity," New England Medical Journal, 263: 935-940, 1960.

34. G. Christakis, S. Sajecki, R.W. Hillman, E. Miller, S. Blumenthal and M. Archer, "Effect of a Combined Nutrition Education and Physical Fitness Program on the Weight Status of Obese High School Boys," Federation Proceedings, 25: 15-19, 1966.

35. J.W. Conn, "Obesity. II. Etiological Aspects," Physiological Reviews, 24: 31-45, 1944.

36. L.A. Cooper, "A Comparison of the Effects of Short Intensive and Prolonged Exercise Programs on Treadmill Performance and Certain Cardio-Respiratory Functions," (unpublished M.Sc. thesis, University of Alberta, 1963).

37. C.B. Corbin and P. pletcher, "Diet and Physical Activity Patterns of Obese and Nonobese Elementary School Children," Research Quarterly, 39: 422-429, 1968.

38. L.L. Coyne, "The Relationship of Maximal Oxygen Intake to Body Composition and Total Body Weight in Active Males," (unpublished M.Sc. thesis, University of Alberta, 1963).

39. E.I. Crews, K.W. Fuge, L.B. Oscai, J.O. Holloszy and R.E. Shank, "Weight, Food Intake and Body Composition: Effects of Exercise and of Protein Deficiency," American Journal of Physiology, 216: 359-363, 1969.

40. G.R. Cumming and P.M. Cumming, "Working Capacity of Normal Children Tested on a Bicycle Ergometer," Canadian Medical Association Journal, 88: 351-355, 1963.

41. G.R. Cumming and R. Danzinger, "Bicycle Ergometer Studies in Children," Pediatrics, 32: 202-208, 1963.

42. G.R. Cumming and L. Young, "Physical Fitness of Nurses," The Canadian Nurse, 61: 289-291, 1965.

43. T.K. Cureton, "Anatomical, Physiological and Psychological Changes Induced by Exercise Programs (Exercises, Sports, Games) in Adults," Exercise and Fitness (Chicago: The Athletic Institute, 1959), pp. 152-182.

44. T.K. Cureton, Physical Fitness Appraisal and Guidance (St. Louis: The C.V. Mosby Company, 1947), pp. 500-509.

45. Cureton, pp. 509-511.

46. T.K. Cureton, "Physical Fitness Improvement of a Middle-Aged Man, with Brief Reviews of Related Studies," Research Quarterly, 23: 149-160, 1952.

47. T.K. Cureton, The Physiological Effects of Exercise Programs on Adults (Springfield: C.C. Thomas, 1969), pp. 52-55.

48. T.K. Cureton and E.E. Phillips, "Physical Fitness Changes in Middle-Aged Men Attributable to Equal Eight-Week Periods of Training, Non-Training and Re-Training," Journal of Sports Medicine and Physical Fitness, 4: 87-93, 1964.

49. R.C. Darling, "The Significance of Physical Fitness," Archives of Physical Medicine, 28: 140-145, 1947.

50. J.A. Dempsey, "Anthropometric Observations on Obese and Nonobese Young Men Undergoing a Program of Vigorous Physical Exercise," Research Quarterly, 35: 276-287, 1964.

51. J.A. Dempsey, W. Reddan, B. Balke and J. Rankin, "Work Capacity Determinants and Physiologic Cost of Weight - Supported Work in Obesity," Journal of Applied Physiology, 21: 1815-1820, 1966.

52. P. deNayer, M. Ostyn and M. De Visscher "Influence of Exercise on Serum Free Thyroxine and Binding Proteins," Biochemistry of Exercise, Medicine and Sport 3, J.R. Poortmans, editor (Baltimore: University Park Press, 1969), pp. 182-187.

53. H.A. de Vries and C.E. Klafs, "Prediction of Maximal Oxygen Intake from Submaximal Tests," Journal of Sports Medicine and Physical Fitness, 5: 207-214, 1965.

54. W. Dock, D. Adlersberg, H.A. Eder, F.E. Kendall and C.F. Wilkinson, Jr., "Current Concepts in the Management of Arteriosclerosis," Bulletin of the New York Academy of Medicine, 31: 198-219, 1955.

55. J. Dolezel, "The Effect of Two Types of Physical Strain during Summer and Winter on Cholesterolemia in Young People," Biochemistry of Exercise, Medicine and Sport 3, J.R. Poortmans, editor (Baltimore: University Park Press, 1969), pp. 148-151.

56. R.J. Dorris and A.J. Stunkard, "Physical Activity: Performance and Attitudes of a Group of Obese Women," American Journal of the Medical Sciences, 233: 622-628, 1957.

57. E.V. Doroschuk, "Physical Working Capacity of Males as Assessed by Bicycle Ergometry," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 243-254.

58. J.V.G.A. Durnin and R. Passmore, Energy, Work and Leisure (London: Heinemann Educational Books, 1967), p. 113.

59. J.V.G.A. Durnin, J.M. Brockway and H.W. Whitcher, "Effects of a Short Period of Training of Varying Severity on Some Measurements of Physical Fitness," Journal of Applied Physiology, 15: 161-165, 1960.

60. B. Ekblom, "Effect of Training on Circulatory Response to Exercise," Physical Activity in Health and Disease, K. Evang and K.L. Andersen, editors (Baltimore: Williams & Wilkins Co., 1966), pp. 15-17.

61. H.P. Elder, "Effects of Training on Middle-Aged Men," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 133-138.

62. E.S. Eppwright, V. Sidwell and E. Jebe, "Food Intake and Body Size of Iowa Children", Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 119-131.

63. J.D. Evans and D.E. Parlee, "Polyethanoid Acids as Energy Sources in Resting and Exercised Rats," Federation Proceedings, 16: 35, 1967.

64. Exercise Tests in Relation to Cardiovascular Function, Report of a WHO Meeting, Number 388 (Geneva: World Health Organization, 1968).

65. A.W. Faris, F.M. Browning and J.D. Ibach, "The Effect of Physical Training upon the Total Serum Cholesterol Levels and Arterial Distensibility of Male White Rats," Journal of Sports Medicine and Physical Fitness, 11: 24-27, 1971.

66. E.L. Fox, C.E. Billings, R. Bason and D.K. Mathews, "Improvement of Physical Fitness by Interval Training," (unpublished research, 1967).

67. M.E. Freedman, G.L. Snider, P. Brostoff, S. Kimelbrot and L.N. Kalz, "Effects of Training on Response of Cardiac Output to Muscular Exercise in Athletes," Journal of Applied Physiology, 8: 39-47, 1955.

68. P.C. Fry "Comparative Study of 'Obese' Children Selected on Basis of Fat Pads," Journal of Clinical Nutrition, 1: 453-467, 1953.

69. S.M. Garn and J. Brozek, "Fat Changes During Weight Loss," Science, 124: 682, 1956.

70. L. Garrett, R.V. Pangle and G.V. Mann, "Effects of Physical Conditioning on Coronary Risk Factors in Men," Federation Proceedings, 24: 262, 1965.

71. M.M. Gertler, S.M. Garn and H.B. Sprague, "Cholesterol, Cholesterol Esters and Phospholipids in Health and in Coronary Heart Disease. II. Morphology and Serum Lipids in Man," Circulation, 1: 380-391, 1950.

72. J.S. Gofman, M. Honig, H.B. Jones, M.A. Laufer, E.Y. Lawry, L.A. Lewis, G.V. Mann, F.E. Moore, F. Ohnstead and J.F. Yeager, "Evaluation of Serum Lipoprotein and Cholesterol Complications of Atherosclerosis," Circulation, 14: 691-741, 1956.

73. L.A. Golding, "Effects of Physical Training upon Total Serum Cholesterol Levels," Research Quarterly, 32: 499-506, 1961.

74. J.W. Gowen and J. Stadler, "Influence of Genotype on Weight Control in Mice," Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 49-63.

75. A.C. Guyton, Textbook of Medical Physiology, 3rd edition (Philadelphia: W.B. Saunders Company, 1966), pp. 1071-1075.

76. Guyton, p. 1070.

77. M.C. Hampton, L.R. Shapiro and R.L. Huenemann, "Helping Teen-age Girls Improve their Diet," Journal of Home Economics, 53: 835-838, 1961.

78. D.L. Hanson, "Effects of Fat to Carbohydrate Ratio on Body Weight and Body Composition of Sedentary and Exercised Rats," Abstracts of Research Papers (Aapher 1967 Convention), p. 4.

79. H.A. Harper, Review of Physiological Chemistry, 12th edition (California: Lange Medical Publications, 1969), p. 450.

80. F.P. Heald, "Basal Oxygen Consumption in the Obese Adolescent," Journal of Pediatrics, 61: 327-330, 1962.

81. T. Hettinger, N.C. Birkhead, J.M. Horvath, B. Issekutz and K. Rodahl, "Assessment of Physical Work Capacity," Journal of Applied Physiology, 16: 153-156, 1961.

82. J.O. Holloszy, J.S. Skinner, G. Toro and T.K. Cureton, "Effects of a Six-Month Program of Endurance Exercise on the Serum Lipids of Middle-Aged Men," American Journal of Cardiology, 14: 733-760, 1964.

83. A. Holmgren, F. Mossfeldt, T. Sjöstrand and G. Ström "Effect of Training on Work Capacity, Total Hemoglobin, Blood Volume, Heart Volume and Pulse Rate in Recumbent and Upright Postures," Acta Physiologica Scandinavica, 50: 72-83, 1960.

84. R.L. Huenemann, "Factors Associated with Teenage Obesity," Obesity, N. Wilson, editor (Philadelphia: F.A. Davis Company, 1969), pp. 55-66.

85. R.L. Huenemann, M.C. Hampton, L.C. Shapiro and A.R. Behnke "Adolescent Food Practices Associated with Obesity," Federation Proceedings, 25: 4-10, 1966.

86. W. Hung, G.P. Gancayco and F.P. Heald, "Thyroxine Metabolism in Obese Adolescent Males," Pediatrics, 36: 877-881, 1965.

87. C.H.G. Irvine, "Thyroxine Secretion Rate in the Horse in Various Physiological States," Journal of Endocrinology, 39: 313-320, 1967.

88. C.H.G. Irvine, "Effect of Exercise on Thyroxine Degradation in Athletes and Non-Athletes," Journal of Clinical Endocrinology and Metabolism, 28: 942-948, 1968.

89. M.J. Jetté, "A Study of Long-Term Physical Activity in Sedentary Middle-Aged Men," (unpublished Ph.D. dissertation, University of Illinois, 1969).

90. M.J. Jetté and J.S. Thoden, "A Profile of the Canadian Cross-Country Ski Team," (unpublished research, 1970).

91. H.L. Johnson, B.S. Burke and J. Mayer, "The Prevalence and Incidence of Obesity in a Cross-Section of Elementary and Secondary School Children," American Journal of Clinical Nutrition, 4: 231-238, 1956.

92. H.L. Johnson, B.S. Burke and J. Mayer, "Relative Importance of Inactivity and Overeating in the Energy Balance of Obese High School Girls," American Journal of Clinical Nutrition, 4: 37-44, 1956.

93. T.F. Johnson, H.Y.C. Wong, R.Y. Shim, K.H.L. Beatrice and A.S. Hall, "The Influence of Exercise on Serum Cholesterol, Phospholipids and Electrophoretic Serum Protein Patterns in College Swimmers," Federation Proceedings, 18: 77, 1959.

94. L.C. Johnston and L.M. Bernstein, "Body Composition and Oxygen Consumption of Overweight, Normal and Underweight Women," Journal of Laboratory and Clinical Medicine, 45: 109-118, 1945.

95. E. Jokl, "Effect of Training Upon Obese and Lean Boys," South African Medical Journal, 1945.

96. E.M. Jones, H.J. Montoye, P.B. Johnson, Sister M.J.M.M. Martin, W.D. Van Huss and D. Cederquist, "Effect of Exercise and Food Restriction on Serum Cholesterol and Liver Lipids," American Journal of Physiology, 207: 460-466, 1964.

97. M.J. Karvonen, "Effects of Vigorous Exercise on the Heart," Work and the Heart, F.F. Rosenbaum and E.L. Belknap, editors (New York: Paul B. Hoeber, Inc., 1959), pp. 201-202.

98. A. Keys, "Body Composition and its Change with Age and Diet," Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 18-29.

99. A. Keys, "Weight Changes and Health of Men," Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 108-118.

100. A. Keys, J. Brozek, A. Henschel, O. Michelson and H.L. Taylor, "The Biology of Human Starvation (Minneapolis: University of Minnesota Press, 1950), pp. 735-742.

101. A. Keys and J. Brozek, "Overweight Versus Obesity and the Evaluation of Caloric Needs," Metabolism, 6: 425-434, 1957.

102. A. Keys, J.T. Anderson, A.M.G. Biorck, J.F. Brodk, B. Bronte-Stewart, F. Fidanze, M.H. Keys, H. Malmros, A. Poppi, T. Posteli, B. Swahn and A. del Vecchio, "Physical Activity and the Diet in Populations Differing in Serum Cholesterol," Journal of Clinical Investigation, 35: 1173-1181, 1956.

103. R.W. Kireilis and T.K. Cureton, "The Relationship of External Fat to Physical Education Activities and Fitness Tests," Research Quarterly, 18: 123-134, 1947.

104. C.A. Knehr, B.D. Dill and W. Neufeld, "Training and the Effect on Man at Rest and at Work," American Journal of Physiology, 136: 148-156, 1942.

105. R.G. Knowlton and H. Weber, "The Effects of Progressive Endurance Training and Voluntary Dietary Restriction on Physique and Metabolic Variables in Markedly Obese Subjects," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 179-194.

106. H.G. Knuttgen, "Aerobic Capacity of Adolescents," Journal of Applied Physiology, 22: 655-658, 1967.

107. S.D. Kobernick, G. Niwayama and A.C. Zuchlewski, "Effect of Physical Activity on Cholesterol Atherosclerosis in Rabbits," Proceedings of the Society for Experimental Biology and Medicine, 96: 623-628, 1957.

108. H.S. Kupperman, Human Endocrinology (Philadelphia: F.A. Davis Company, 1963), p. 835.

109. D. Kritchevsky, Cholesterol (New York: John Wiley & Sons, Inc., 1958), pp. 181-182.

110. Kritchevsky, p. 165.

111. S. Larsson,"Factors of Importance for the Etiology of Obesity," Acta Physiologica Scandinavica, Supplement 294, 1967.

112. J.C. Lashof, P.K. Bondy, K. Sterling and E.B. Man, "Effect of Muscular Exercise on Circulating Thyroid Hormone," Proceedings for the Society of Experimental Biology (New York), 86: 233-234, 1954.

113. L.A. Lewis, F. Olmstead, I.H. Page, E.Y. Lawry, G.V. Mann, F.J. Stare, M. Hanig, M.A. Lauffer and F.E. Moore, "Serum Lipid Levels in Normal Persons. Findings of a Cooperative Study of Lipoproteins and Athosclerosis," Circulation, 26: 227-245, 1957.

114. K. Linroth, "Testing Physical Working Capacity in Military Personnel," Acta Medica Scandinavica, Försvarsmedicin, 3: 167-171, 1967.

115. E.S. Livas, "Cholesterolaemia and Arteriosclerosis," Klin. Med. Mosk., 38: 137, 1957.

116. C.M. MacBryde, "The Diagnosis of Obesity," The Medical Clinics of North America, 48: 1307-1316, 1964.

117. 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.

118. M.S. Malhotra, S.S. Ramaswamy and S.N. Ray, "Influence of Body Weight on Energy Expenditure," Journal of Applied Physiology, 17: 433-435, 1962.

119. R.M. Malina, "Exercise as an Influence upon Growth," Clinical Paediatrics, 8: 16-26, 1969.

120. J. Mayer, "Genetic, Traumatic and Environmental Factors in the Etiology of Obesity," Physiological Reviews, 33: 422-508, 1953.

121. J. Mayer, "Regulation of Food Intake and the Multiple Etiology of Obesity," Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 29-48.

122. J. Mayer, "Obesity: Etiology and Pathogenesis," Post-graduate Medicine, 25: 623-634, 1959.

123. J. Mayer, "The Obese Hyperglycemic Syndrome of Mice as an Example of 'Metabolic' Obesity," American Journal of Clinical Nutrition, 8: 740-745, 1960.

124. J. Mayer, "Genetic Factors in Obesity," Bulletin of the New York Academy of Medicine, 36: 323-343, 1960.

125. J. Mayer, "Exercise and Weight Control," Exercise and Fitness (Chicago: The Athletic Institute, 1959), pp. 110-121.

126. J. Mayer, "Obesity: Physiologic Considerations," American Journal of Clinical Nutrition, 9: 530-537, 1961.

127. J. Mayer, "Physical Activity and Anthropometric Measurements of Obese Adolescents," Federation Proceedings, 25: 11-14, 1966.

128. J. Mayer, Overweight, Causes, Cost and Control (Englewood-Cliffs, New Jersey: Prentice-Hall, Inc., 1968).

129. J. Mayer, N.B. Marshall, J.J. Vitale, J.H. Christensen, M.B. Mashayekhi and F.J. Stare, "Exercise, Food Intake and Body Weight in Normal Rats and Genetically Obese Adult Mice," American Journal of Physiology, 177: 544-548, 1954.

130. J. Mayer, P. Roy and K.P. Mitra, "Relation Between Caloric Intake, Body Weight and Physical Work in an Industrial Male Population in West Bengal," American Journal of Clinical Nutrition, 4: 169-175, 1956.

131. J. Mayer, C. Zomzely and F.J. Stare, Experimentia, 13: 250, 1957.

132. W.D. McArdle and J.R. Magel, "Physical Work Capacity and Maximum Oxygen Uptake in Treadmill and Bicycle Exercise," Medicine and Science in Sports, 2: 118-123, 1970.

133. B.J. McAtte and S. Grollman, "The Effects of Exercise and Training on the Hematology of the Female Albino Rat," Journal of Sports Medicine and Physical Fitness, 7: 205-213, 1967.

134. B.H. McCracken, "Etiological Aspects of Obesity," Chronic Diseases and Public Health (Baltimore: The John Hopkins Press, 1966), pp. 125-137.

135. W.C. McNelly, "Some Effects of Training on the Respiratory Response to Exercise," American Journal of Physiology, 116: 100-101, 1936.

136. G. Métivier, "Changes in the Total Blood Serum Cholesterol Level, Cardiovascular Condition and Adiposity of Adult Males Following One Season of Ice Hockey," Medical Services Journal of Canada, 22: 411-422, 1966.

137. A.T. Miller and C.S. Blythe, "Influence of Body Type and Body Fat Content on the Metabolic Cost of Work," Journal of Applied Physiology, 8: 139-141, 1955.

138. D.S. Miller and P. Mumford, "Obesity: Physical Activity and Nutrition," Proceedings of the Nutrition Society, 24-25: 100-107, 1965-66.

139. J.H. Mitchell and G. Blomquist, "Maximal Oxygen Uptake," New England Journal of Medicine, 284: 1018-1022, 1971.

140. J.M. 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.

141. D.R. Mohr, "Changes in Waistline and Abdominal Girth and Subcutaneous Fat Following Isometric Exercises," (unpublished research, 1964).

142. H.J. Montoye, W.D. Van Huss, W.D. Brewer, E.M. Jones, M.A. Ohlson, E. Mahoney and H. Olson, "The Effects of Exercise on Blood Cholesterol in Middle-Aged Men," American Journal of Clinical Nutrition, 7: 139-145, 1959.

143. D.L. Moody, J. Kollias and E.R. Buskirk "Evaluation of Aerobic Capacity in Lean and Obese Women with Four Test Procedures," *Journal of Sports Medicine and Physical Fitness*, 9: 1-9, 1969.

144. F.E. Moore, "Serum Cholesterol Levels of Adults," (United States 1960-62), *National Centre for Health Statistics*, 11: 1-23, 1967.

145. M.E. Moore, A. Stunkard and L. Srole, "Obesity, Social Class and Mental Illness," *Journal of the American Medical Association*, 181: 962-966, 1962.

146. L.E. Morehouse and A.T. Miller, *Physiology of Exercise*, 5th edition (St. Louis: The C.V. Mosby Company, 1967), p. 254.

147. A.L. Myasnikov, "Influence of Some Factors on Development of Experimental Cholesterol Atherosclerosis," *Circulation*, 17: 99-113, 1958.

148. J. Naughton and B. Balke, "Physical Working Capacity in Medical Personnel and the Response of Serum Cholesterol to Acute Exercise and to Training," *American Journal of the Medical Sciences*, 247: 286-292, 1964.

149. J. Naughton and J.F. McCoy, "Observations on the Relationship of Physical Activity to the Serum Cholesterol Concentration of Healthy Men and Cardiac Patients," *Journal of Chronic Diseases*, 19: 727-733, 1966.

150. J. Naughton and F. Nagle, "Peak Oxygen Intake during Physical Fitness Program for Middle-Aged Men: Measurement of Changes by Laboratory and Field Testing," *Journal of the American Medical Association*, 191: 899-901, 1965.

151. L.H. Newburg and M.W. Johnston, "The Nature of Obesity," *American Journal of Physiology*: 197-213, 1929.

152. F. Newman, B.F. Smalley and M.L. Thomson, "Effect of Exercise, Body and Lung Size on CO Diffusion in Athletes and Non-Athletes," *Journal of Applied Physiology*, 17: 649-655, 1962.

153. L.B. Oscai and B.T. Williams, "Effects of Exercise on Overweight Middle-Aged Males," *Journal of the American Geriatrics Society*, 16: 794-797, 1968.

154. J. Parizkova, "Physical Activity and Body Composition," Human Body Composition, J. Brozek, editor (London: Permagon Press, 1965), pp. 161-176.

155. J. Parizkova and L. Stankova, "Influence of Physical Activity on a Treadmill on the Metabolism of Adipose Tissue in Rats," British Journal of Nutrition, 18: 325-332, 1964.

156. S. Passen and R. von Saleski, "A Semiautomated Method Which Does Not Require Digestion for the Determination of Serum Thyroxine Iodine (T_4)," American Journal of Clinical Pathology, 15: 166-176, 1969.

157. R. Passmore, "A Note on the Relation of Appetite to Exercise," Lancet, 4: 29, 1958.

158. R. Passmore and J.V.G.A. Durnin, "Human Energy Expenditure," Physiological Reviews, 35: 801-840, 1955.

159. P. Peckos, J. Spargo and F. Heald, "Program and Results of a Camp for Obese Adolescent Girls," Postgraduate Medicine, 27: 527-533, 1960.

160. G.C. Pitts, "Body Fat Accumulation in the Guinea Pig," American Journal of Physiology, 185: 41-48, 1956.

161. H. Pollack, C.F. Consolazio and G.J. Isaac, "Metabolic Demands as a Factor in Weight Control," Journal of the American Medical Association, 167: 216-219, 1958.

162. M.L. Pollack, T.K. Cureton and M.S. Greninger, "Effects of Frequency of Training in Work Capacity, Cardiovascular Function and Body Composition of Adult Men," Medicine and Science in Sports, 1: 70-74, 1969.

163. S. Reichlin, M.G. Koussa and F.W. Witt, "Effect of Prolonged Sleep Therapy and of Chlorpromazine on Plasma Protein-Bound Iodine Concentration and Plasma Thyroxine Turnover," Journal of Clinical Endocrinology, 19: 692-699, 1959.

164. B.A. Rhodes, "Effect of Exercise on the Thyroid Gland," Nature, 216: 917-918, 1967.

165. P.M. Ribsl, "Changes in Maximal Oxygen Intake with Training in Middle-Aged Men," Abstracts of Research Papers, (Aapher 1967 Convention), p. 13.

166. J.C. Roberts and R.H. Wilkins, "Atherosclerosis in Obese Patients at Autopsy," Circulation, 18: 495, 1958.

167. S. Robinson, "Metabolic Adaptations to Exhausting Work as Affected by Training," American Journal of Physiology, 133: 428, 1941.

168. S. Robinson and P.M. Harmon, "Effects of Training and of Gelatin upon Certain Factors Which Limit Muscular Work," American Journal of Physiology, 133: 161-169, 1941.

169. S. Robinson, H.T. Edward and D.B. Dill, "New Records in Human Power," Science, 85: 409-410, 1937.

170. F.B. Roby, "Effect of Exercise on Regional Fat Accumulation," Research Quarterly, 33: 273-277, 1962.

171. R.H. Rochelle, "Blood Plasma Cholesterol Changes During a Physical Training Program," Journal of Sports Medicine and Physical Fitness, 1: 63-70, 1961.

172. K. Rodahl, P.-O. Astrand, N.C. Birkhead, T. Hettinger, B. Issekutz, D.M. Jones and R. Weaver, "Physical Work Capacity," Archives of Environmental Health, 2: 499-510, 1961.

173. R.B. Rowell, H.L. Taylor and Y. Wong, "Limitations to Prediction of Maximal Oxygen Intake," Journal of Applied Physiology, 19: 919-927, 1964.

174. M. Schade, F.A. Hellebrandt, J.C. Waterland and M.L. Carns, "Spot Reducing in Overweight College Women: Its Influence on Fat Distribution as Determined by Photography," Research Quarterly, 33: 461-540, 1962.

175. E.C. Schneider and C.B. Crampton, "A Comparison of Some Respiratory and Circulatory Reactions of Athletes and Non-Athletes," American Journal of Physiology, 129: 165-170, 1940.

176. V. Seliger and V. Zelenka, "Physical Fitness of Czech Children at 12 and 15 Years of Age," Acta Universitatis Carolinae Gynica, 5, 1970.

177. C.C. Seltzer and J. Mayer, "Serum Iron and Iron-Binding Capacity in Adolescents. II. Comparison of Obese and Non-Obese Subjects," American Journal of Clinical Nutrition, 13: 354-361, 1963.

178. T. Sjostrand, "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," *Acta Medica Scandinavica*, 196: 687-699, 1947.

179. T. Sjostrand, "The Significance of the Pulmonary Blood Volume in the Regulation of the Blood Circulation Under Normal and Pathological Conditions," *Acta Medica Scandinavica*, 145: 155-168, 1953.

180. T. Sjostrand, "Testing of the Physical Working Capacity. Definition, History and Application," *Acta Medica Scandinavica, Försvarsmedicin*, 3: 141-144, 1967.

181. J.S. Skinner, J.O. Holloszy and T.K. Cureton, "Effects of a Program of Endurance Exercises on Physical Work," *American Journal of Cardiology*, 14: 747-752, 1964.

182. J.S. Skinner, G.A. V. Borg and E.R. Buskirk, "Physiological and Perceptual Reactions to Exertion of Young Men Differing in Activity and Body Size," *Exercise and Fitness* (Chicago: The Athletic Institute, 1969), pp. 53-66.

183. N. Skold, "Training of Conscripts and Ordinary Military Personnel," *Acta Medica Scandinavica, Försvarsmedicin*, 3: 175-182, 1967.

184. S. Sprynarova and J. Parizkova, "Changes in the Aerobic Capacity and Body Composition in Obese Boys After Reduction," *Journal of Applied Physiology*, 20: 934-937, 1965.

185. P.A. Stefanik, B. Bullen, F.P. Heald and J. Mayer, "Physical Performance, Skinfold Measurements, Activity Expenditures and Food Consumption of College Women," *Research Quarterly*, 32: 229-237, 1961.

186. P.A. Stefanik, F.P. Heald and J. Mayer, "Caloric Intake in Relation to Energy Output of Obese and Nonobese Adolescent Boys," *American Journal of Clinical Nutrition*, 7: 55-61, 1959.

187. G. Strom, "Recommended Symbols, Nomenclature and Criteria for Certain Measures of Physical Capability," *Acta Medica Scandinavica, Försvarsmedicin*, 3: 159-160, 1967.

188. A. Stunkard, "Physical Activity, Emotions and Human Obesity," _American Practitioners and Digest of Treatment_, 10: 1500-1, 1959.

189. A. Stunkard and J. Pestka, "The Physical Activity of Obese Girls," _American Journal of Clinical Nutrition_, 103: 812-817, 1963.

190. J.M. Tanner, "The Relation Between Serum Cholesterol and Physique in Healthy Young Men," _Journal of Physiology_, 115: 371-390, 1951.

191. C. Taylor, "Studies in Exercise Physiology," _American Journal of Physiology_, 135: 27-42, 1941-42.

192. H.L. Taylor, J.A. Anderson and A. Keys, "Effect on Serum Lipids of 1300 Calories of Daily Walking," _Federation Proceedings_, 16: 128, 1957.

193. 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, 1955.

194. The Canadian Association for Health, Physical Education and Recreation, _The Physical Work Capacity of Canadian Children_, 1968.

195. The Canadian Association for Health, Physical Education and Recreation, _The Physical Fitness Performance and Work Capacity of Canadian Adults Aged 18 to 44 Years_, 1971.

196. B.M. Thomas and A.T. Miller, "Adaptation to Forced Exercise in the Rat," _American Journal of Physiology_, 193: 350-354, 1958.

197. C.W. Thompson, "Changes in Body Fat Estimated from Skinfold Measures of Varsity College Football Players during a Season," _Research Quarterly_, 30: 87-93, 1959.

198. C.W. Thompson, E.R. Buskirk and R.F. Goldman "Changes in Body Fat Estimated from Skinfold Measures of College Basketball and Hockey Players during a Season," _Research Quarterly_, 27: 418-430, 1956.

199. C.D. Turner, _General Endocrinology_, 4th edition (Philadelphia: W.B. Saunders Company, 1965), p. 205.

200. Turner, p. 206.

201. A.R. Ubbelohde, *Man and Energy* (Great Britain: Pelican Books Ltd.. 1963), pp. 127-128.

202. R. Volpé, J. Vale and W.J. MacAllister, "The Effects of Certain Physical and Emotional Tensions and Strains on Fluctuations in the Level of Serum Protein-Bound Iodine," *Journal of Clinical Endocrinology*, 20: 415-428, 1960.

203. W. Von Döbeln, "Human Standard and Maximal Metabolic Rate in Relation to Fat-Free Body Mass," *Acta Physiologica Scandinavica*, 37, Supplement 126, 1956.

204. H.G. Wahlund, "Determination of the Physical Working Capacity: A Physiological and Clinical Study with Special Reference to Standardization of Cardio-Pulmonary Functional Tests," Acta Medica Scandinavica, 132, Supplement 215: 9-86, 1948.

205. N.H. Warnock, T.B. Clarkson and R. Stenvenson, "Effect of Exercise on Blood Coagulation Time and Atherosclerosis of Cholesterol-Fed Cockerels," *Circulation Research*, 5: 478-480, 1957.

206. 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, 1958.

207. J.B. Wells, J. Parizkova and E. Jokl, "The Kentucky Physical Fitness Experiment," *Journal of the Association for Physical and Mental Rehabilitation*, 15-17: 69-72, 1961-63.

208. J.B. Wells, J. Parizkova, J. Bohanan and E. Jokl, "Growth, Body Composition and Physical Efficiency," *Journal of the Association for Physical and Mental Rehabilitation*, 15-17: 37-40, 1961-63.

209. B.J. Wenzell, H. Stults and J. Mayer, "Hypoferremia in Obese Adolescents," *Lancet*, 2: 327, 1962.

210. R.I. White and J.K. Alexander, "Body Oxygen Consumption and Pulmonary Ventilation in Obese Subjects," *Journal of Applied Physiology*, 20: 197-201, 1965.

211. R.H. Williams, "Relation of Obesity to the Function of the Thyroid Gland, Especially as Indicated by the Protein-Bound Iodine Concentration in the Plasma," *Journal of Clinical Endocrinology and Metabolism*, 8: 257-261, 1948.

212. C.F. Wilkinson, E.A. Hand and N.T. Flieglman, "Essential Familial Hypercholesterolemia," *Annals of Internal Medicine*, 29: 671, 1948.

213. O. Wilson, "Field Study of the Effect of Cold Exposure and Increased Muscular Activity upon Metabolic Rate and Thyroid Function in Man," *Federation Proceedings*, 25: 1357-1362, 1966.

214. H.Y.C. Wong, M.B. Anderson, J.K. Lin, D.J. Liu and E.W. Hawthorne, "Hypocholesterolizing Effect of Exercise on Cholesterol-Fed Cockerels," *Proceedings of the Federation of American Societies for Experimental Biology*, 16: 138, 1957.

215. M. Wurm, R. Kositchek and R. Straus, "Lipoprotein Quantitated by Paper Electrophoresis as an Index of Atherosclerosis," *Circulation*, 21: 526-537, 1960.

216. B.W. Wyden, "Overweight? - A Fresh Look at the Problem," *Reader's Digest*, January 1971, pp. 59-62.

217. C.M. Young, "The Prevention of Obesity," *The Medical Clinics of North America*, 48: 1317-1333, 1964.

CHAPTER III

METHODS AND MATERIALS

Introduction

The objective of this study was to determine the response of selected physiological and anthropometric parameters of obese male adolescents engaged in a 5 month lacrosse program.

It is the purpose of this chapter to describe the experimental procedures observed throughout this study. The selection of subjects, the experimental treatment, the experimental period, testing procedures, apparatus used and the statistical tools employed are described.

Selection of Subjects

The subjects were selected from two secondary schools in Ottawa, Ontario on the basis of physical appearance, height and weight by the school nurse. The experimental group was composed of 11 obese adolescents of the Académie de La Salle, Ottawa, and the control group of ten obese adolescents of the University of Ottawa High School. All subjects were male, between 14 and 17 years of age and Caucasian. No effort was made to randomize the selection of subjects.

A letter of consent was sent to the parents of each subject following selection by the school nurse, briefly informing them of the nature and advantage of a physical activity program and requesting permission for their son's participation. (Appendix A)

Experimental Treatment

The game of lacrosse was selected as the basis of the physical activity program for this study because:

1. The experimental treatment could be controlled.
2. It employs all major muscle groups.
3. It is excellent for the development of organic efficiency, and the development of coordination, balance, and agility. It also promotes team participation and social interaction, of great importance to adolescents.

The experimental group began the lacrosse program on December 1, 1970 and terminated it on April 30, 1971, after a period of approximately 5 months. Essentially, the program consisted of two three-quarter hour periods of lacrosse per week, held on two afternoons (from 3:30 to 4:20 p.m.) following the cessation of the regular day classes. That is, the program was not considered as part of the regular physical education program; rather, the subjects of the experimental group all took physical education as a required course.

The lacrosse program was conducted by two physical education teachers at the Académie de la Salle. The type of program which is the experimental treatment for this study was carried out by two instructors based on the booklet

"Lacrosse" by the Canadian Fitness and Amateur Sport Directorate. That is, the six lessons described below were taught over an initial period of approximately 6 weeks to introduce new skills in relatively the same order as cited in the book. It must be noted that the program began December 1, 1970 but was interrupted approximately the latter two weeks of December by examinations and holidays. Attendance records were kept commencing January 6, 1971. A slight decrease in attendance after 6 weeks was noticed by the instructors. To stimulate more interest in the program it was decided to divide the experimental group into two teams to play lacrosse competetively against each other for the remaining 14 weeks. More specifically, in those weeks each period of lacrosse began with approximately 5 minutes of warm-up (throwing, receiving, plays,etc.) carried out by the group on their own. For the remainder of the period, the two teams played a lacrosse match. The instructors stopped play intermittently to correct obvious errors in rules and skills.

The booklet on lacrosse was also distributed to each member of the experimental group. The following lessons indicate the content of the program for the initial 6 weeks.

Lesson 1:	Pre-lesson	-	Individual work-out.
	Introduction	-	Stick, care of equipment, discussion of lacrosse book.
	Skills	-	Stick handling. Activity-relays holding stick.

\- Trapping (scoop, pick up). Activity-pick up ball, run around.

Game Relay - last 10 minutes.

Lesson 2: Pre-lesson - Fitness work-out.

Skills - Passing (overhand, underhand). Activity - passing, throwing against wall.

\- Passing to a receiver (overhand, underhand). Activity - passing ball to partner.

Game

Lesson 3: Pre-lesson - Fitness work-out.

Skills - Circuit (pick up ball, spin around, shoot).

Games - Shooting for accuracy.

Lesson 4: Pre-lesson - Fitness work-out.

Skills - Receiving a pass (stationary receiver, moving receiver). Activities receiving pass stationary, receiving pass moving and shoot at goal (drills).

Game

Lesson 5: Pre-lesson - Fitness work-out.

Skills - Passing drills. Activity - two lines, criss-cross and receiving pass moving.

- Two on one play.

Game - As many points as possible with a time limit.

Lesson 6: Pre-lesson - Fitness work-out.

Skills - (stressing game sense)

- Two on two play, three on two play.

Game

The response of the subjects of the experimental group to the lacrosse program as indicated by the attendance records was fairly good; the subjects attended an average of 80% of the total sessions.

Experimental Period

Pre-tests were administered to the experimental group the last two weeks of November, 1970. Following this, the control group was pre-tested the first two weeks of December. The lacrosse program for the experimental group began December 2, 1970 and terminated April 30, 1971. Following its conclusion, both the experimental and control groups were retested again.

Testing Procedures

The retesting procedure, minus the medical examination, was essentially identical to the subjects' initial testing period prior to the five-month lacrosse program. The pre-tests were administered in two different sessions for each subject as described below:

First Session: Medical Examination and Blood Analysis. The tests given at this session and indicated in Table 4 were administered during the afternoon hours. The experimental group was tested three weeks before the control group.

1. Medical Examination. All members of the experimental group underwent a complete medical examination at the Ottawa Civic Hospital on the same day of the second last week of November, actually during the first week of pre-testing of this group. The medical examination for the control group was held for all on the same day of the second week of December, during the first week of pre-testing of this group. It was required that all subjects be in a state of good general health as determined by a medical examination before participating in the lacrosse program.

2. Blood Analysis. Forty-seven cubic centimetres of venous blood were drawn by the nurse technician at the Ottawa Civic Hospital Laboratory with the subject in a sitting position.

A sample of serum was analyzed for thyroxine by the National Defence Hospital Laboratory according to the method outlined by Passen and von Saleski (6).

Hemoglobin, hematocrit and cholesterol determinations were carried out by the Biokinetics Laboratory technician at the University of Ottawa within two hours, following blood collection. A whole blood sample was analyzed for hemoglobin and cholesterol, the latter according to the method of Watson (12) and Zöllner (13). Hematocrit determinations were carried out on an heparinized venous blood sample.

Second Session: Work Capacity and Anthropometric Tests. The work capacity and anthropometric tests indicated in Table 4 were administered to both the experimental and control groups on weekdays between 3:30 and 5:30 p.m.

1. Work Capacity Test. A modified form of the PWC_{170} exercise test as developed by Sjostrand (7), modified by Wahlund (11), and subsequently used in Canada in connection with the CAHPER adult and youth fitness norm developmental research (9) (10) was employed.

Upon arrival at the laboratory, the subject was asked to remove all outer clothing with the exception of his shorts or trousers, and shoes and socks.

Three chest electrodes (leads RA, LA, LL) were secured on the subject with the aid of Sanborn Redox electrode paste to improve conduction.

The subject was asked to mount a bicycle ergometer. The height of the bicycle seat was adjusted so that when the subject was seated the knee was slightly bent when the lower pedal rested directly below the longitudinal arch of the foot. The patient lead from the electrodes was plugged into a pre-amplifier of the polygraph. In the next few minutes, the work capacity test was briefly explained to the subject to

Table 4

Selected Physiological and Anthropometric Tests Administered in the Initial and Final Testing Sessions

Category	Test Description	Units
Blood Analysis	Hematocrit (Ht)	% hematocrit
	Hemoglobin (HB)	Grams/100 millilitres blood
	Cholesterol (Chol)	Milligrams/100 millilitres serum
	Thyroxine (T_4)	Microgram/100 millilitres blood
Work Capacity Test	Heart rate (EKG)	Beats per minute
	Oxygen consumption (VO_2)	Litres/min., litres/kg/min STPD
	Respiratory quotient (RQ)	
	Oxygen pulse (O_2 pulse)	Millilitres/beat
Anthropometric	Height	Inches
	Weight	Pounds
	Fat	%
	Fat-free body weight	Pounds
	Shoulder width	Inches
	Chest breadth	Inches
	Hip width	Inches
	Knee width	Inches
	Chest depth	Inches
	Biceps girth	Inches
	Chest normal	Inches
	Chest inflated	Inches
	Chest deflated	Inches
	Abdominal girth	Inches

Table 4 (continued)

Category	Test Description	Units
Anthropometric	Gluteal girth	Inches
	Thigh girth	Inches
	Calf girth	Inches
	Ankle girth	Inches
	Arm span	Inches
	Sitting height	Inches
Skinfold	Cheeks	Millimetres
	Mid axilla	Millimetres
	Chest	Millimetres
	Abdomen	Millimetres
	Hips	Millimetres
	Subscapular	Millimetres
	Triceps	Millimetres
	Gluteals	Millimetres
	Front thigh	Millimetres
	Rear thigh	Millimetres
	Biceps	Millimetres

familiarize and avoid any apprehension on his part.

Pre-exercise heart rate was noted on an electrocardiotachograph and an attempt made to relax the subject so that the heart rate remained below 100 BPM.

The rate of pedalling was established by the use of an electric metronome placed in front of the subject to offer both an auditory and visual (by means of flashing light on top of metronome) stimulus at a set rate of 120 single beats per minute. The frequency ensured that 60 complete revolutions of the pedal occured each minute. The subject was allowed to adjust to the pace with no load, but when achieved, the first load was set and a clock commenced timing.

The sequence of events for the work capacity test is outlined in Table 5. During the entire test (0-22 min) a noseclip was maintained on the subject's nose and breathing occured only through a mouthpiece.

During the initial resting period, exercise and recovery, the heart rate of the subject was continuously monitored on the electrocardiotachograph. If the subject's heart rate during the first workload exceeded 130 BPM, it was noted on the polygraph recording and if it exceeded 160, the test was terminated. Similarly, the values respectively for the second and third workloads were 145, 170 and 165, 180 respectively.

During the recovery phase of exercise, the volume of expired gas over the five minute recovery period was determined by the use of a Kofranyi-Michaelis respirometer. The use of this instrument was included in this test due to the fact that the study was conducted in conjunction with another experiment which utilized the same subjects and exercise test as a source of data.

2. Anthropometric Tests. The anthropometric tests listed in Table 4 were administered by a member of the laboratory staff. The procedure for the administration of these tests is outlined in Cureton's texts (1, 2, 3).

Apparatus

Hemoglobin. Hemoglobin determinations were carried out on whole blood samples by the cyanmethemoglobin method. Acudyl diluent (6 ml) is pipetted into a cuvette marked blank, and an equal quantity into another cuvette marked unknow. To the latter, 0.02 ml. of whole blood is added, the contents are mixed together and then allowed to stand 10 minutes to permit cyanmethemoglobin to form. The blank is used to adjust a spectrophotometer (wavelength at 540 mu) (Bausch + Lamb) to zero optical density. The unknown is then placed in the spectrophotometer and its optical density recorded. To find gm % hemoglobin of the whole blood sample, reference is made to a standard curve.

Hematocrit. In an hematocrit determination, venous blood is drawn into two micro-hematocrit tubes heparinized to 75 mm of length, and the opposite ends are sealed with plasticine. The capillary tubes are centrifuged at 3,000

R.P.M. for 4 minutes and the % hematocrit is read directly from a scale in the head of the centrifuge.

Cholesterol. Cholesterol concentration in serum was determined according to the method of Watson (12) and Zöllner (13). Each determination of cholesterol in a sample required a standard and a blank. Into a test tube marked blank, 0.1 ml. of distilled water is pipetted, into one marked standard, 0.1 ml. of a solution (200 mg % cholesterol in glacial acetic acid) and into a test tube marked sample, 0.1 ml. of serum. To all three test tubes, 2.5 ml. of a solution (0.05 M dimenthylbenzene sulphuric acid; 7.0 acetic acid; 6.5 M acetic anhydride) are added by pipetting. The tubes are mixed, and allowed to stand in a water bath 5 minutes at 20-25°C, following which 0.5 ml. sulphuric acid is added. The tubes are mixed quickly and kept in the water bath for another 10 minutes. The solutions are then poured into dry cuvettes, and the optical densities of the sample (E_{sample}) and standard ($E_{standard}$) are read against the blank (using Bausch-Lamb spectrophotometer). The mg. cholesterol/100 ml. serum are calculated according to ($E_{sample} \div E_{standard}$) x 200.

Thyroxine. Thyroxine concentration in serum was determined according to the method of Passen and von Saleski, a semiautomated method for the determination of serum thyroxine iodine (T_4) (6).

The Ergometer. The bicycle ergometer used in the study was of the von Döbeln type manufactured by the Monark Company in Varberg, Sweden and modified according to the CAHPER fitness norm developmental study (9) (10). The modifications enable a combination of greater range of seat height, shorter pedal arms and a lighter pendulum allowing lighter work loads and finer work load degradations. The gearing and circumference of the wheel are so dimensioned that one complete turn of the pedals moves a point on the rim 6 meters. The maximum load setting is 7 kiloponds (kp).

Work Capacity Test (Cardio-Respiratory Variables). The basic system for measuring the cardio-respiratory variables (Figure 1) in response to sitting rest, ergometer exercise at standardized loads and sitting recovery consisted of a conventional open circuit (Appendix B) which was used to take intermittent volume collections and samples of expired gas. The subject on the bicycle ergometer breathed through a triple "J" high velocity valve (Collins, dead space 180 cc.), passing all of his expired air into a calibrated 350 litre Collins Chain-Compensated Tissot gasometer when volume collections were desired. A three-way large-bore aluminum stopcock inserted between the exit valve of the mouthpiece assembly and the gasometer was positioned "subject to gasometer" when expired gas collections were desired and "subject to the outside" when not. Volume measurements in the tissot gasometer during rest and exercise were noted by observing the meter stick (mm.

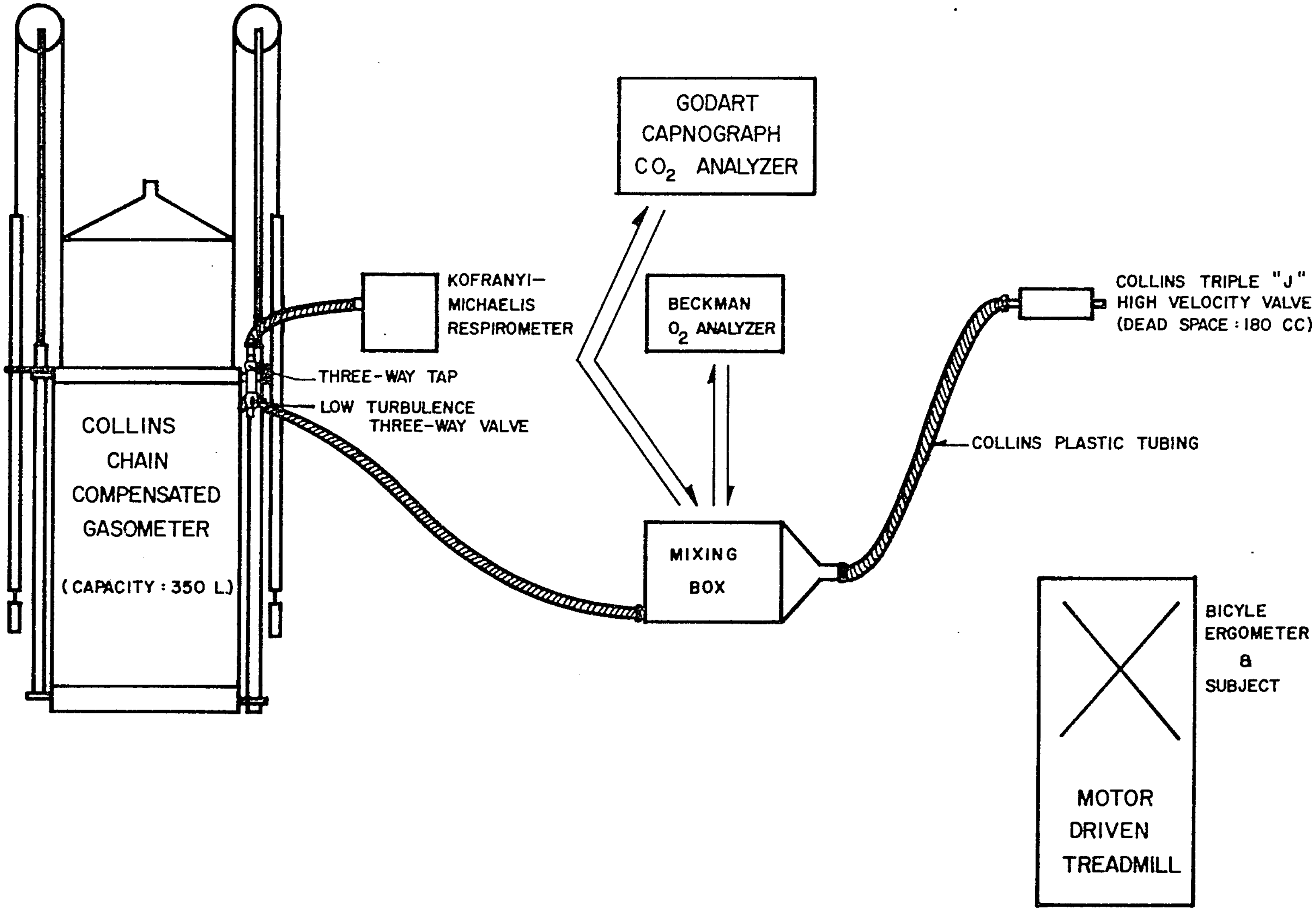

FIG. **1** Schematic Drawing of Open-Circuit for Obtaining Work Capacity Test (Cardio-Respiratory Variables) Data

Table 5

Testing Sequence for Work Capacity Test

Minutes	Conditions	Activity	Recordings
0-5	Rest	Sitting (bicycle)	Initial KM Reading 4th-5th minute: heart rate (EKG) respiratory frequency (f) ventilation deflection(tissot) KM reading Tissot, KM temperatures expired gas (CO_2, O_2) analysis (15th, 30th, 45th, 60th second)
5-9	Test - ride 4 minutes first workload	Bicycle ergometer 360 Kpm/min. 60 r.p.m.	4th-5th minute: heart rate (EKG) respiratory frequency (f) ventilation deflection(tissot) KM reading Tissot, KM temperatures expired gas (CO_2, O_2) analysis (15th, 30th, 45th, 60th second)
9-13	Test - ride 4 minutes second workload	Bicycle ergometer 720 Kpm/min. 60 r.p.m.	4th-5th minute: heart rate (EKG) respiratory frequency (f) ventilation deflection(tissot) KM reading Tissot, KM temperatures

Table 5 (continued)

Minutes	Conditions	Activity	Recordings
			expired gas (CO_2, O_2) analysis (15th, 30th, 45th, 60th seconds)
13-17	Test - ride 4 minutes third workload	Bicycle ergometer 1080 Kpm/min. 60 r.p.m.	Initial KM Reading 4th-5th minute:: heart rate (EKG) respiratory frequency (f) ventilation deflection(tissot) KM reading Tissot, KM temperatures expired gas (CO_2, O_2) analysis (15th, 30th, 45th, 60th second)
17-22	Post - exercise	Sitting (bicycle)	Last 5 seconds of each minute: heart rate (EKG) respiratory frequency (f) Each minute: expired gas (CO_2, O_2) analysis (15th, 30th, 45th, 60th second) End of 5th minute: KM reading and temperature

measuring scale). Also connected to the circuit was a Kofranyi-Michaelis respirometer utilized to record the volume of gas expired during the five minute recovery period from exercise.

Expired gas was analyzed for specific gas concentrations using a Beckman Electronic Oxygen Analyzer (Model E-2, magnetic) and a Godart Electronic Capnograph.

Respiratory frequency and heart rate (EKG) were recorded by a Sanborn polygraph (7700 Series, Hewlett and Packard). To record heart rate (EKG), the patient lead from the subject was plugged into pre-amplifier #6 of the polygraph, and the function control was set at AVL which is the lead system compatible with the RA, LA, RL leads. Recordings were obtained at a paper speed of 2.5 mm/sec. during rest and exercise, and at 25 mm/sec. during recovery. Heart rate was also constantly monitored on a Sanborn electrocardiotachograph (Model 768-100, 760 Monitor Score, Hewlett and Packard) (Appendix B).

Anthropometric Measurements. The following pieces of equipment were used for anthropometric measurements: Skinfold calipers (John Bull British Indicators), a breadth caliper, a measuring tape (in inches), a yard stick (in inches) and a ruler caliper (in inches).

Statistical Analysis

The initial group means for all tests were compared by analysis of variance (4) to determine whether there existed any significant differences (.01 and .05 levels) between the experimental and control groups at the initial testing sessions. If significant differences did exist, the analysis of co variance (5) was employed to determine if any significantly different changes (.01 and .05 levels) existed between the two groups at the retesting sessions. The analysis of variance was used, however, if the groups did not differ significantly at the initial testing sessions.

The computations were carried out on the University of Ottawa IBM 360 computer using the SOUPAC (8) program on the raw data for the analysis of variance. The sum of squares and mean squares between and within groups, degrees of freedom and the resulting F ratio was printed out by the computer.

The subjects in this study may not be considered a random sample. Generalizations, as a result of this study, must therefore be limited to this sub-population only.

REFERENCES

Chapter III

1. T.K. Cureton, *Physical Fitness Appraisal and Guidance* (St. Louis: The C.V. Mosby Company, 1947).

2. T.K. Cureton, *Physical Fitness Workbook* (Champaign: Stipes Publishing Co., 1944).

3. T.K. Cureton, *et al.*, *Endurance of Young Men* (Washington: Society for Research in Child Development, 1945).

4. A.L. Edwards, *Experimental Design in Psychological Research*, 3rd edition (New York: Holt, Rinehart and Winston, Inc., 1968), p. 115.

5. Edwards, p. 326.

6. S. Passen and R. von Saleski, "A Semiautomated Method Which Does Not Require Digestion for the Determination of Serum Thyroxine Iodine (T_4),", *American Journal of Clinical Pathology*, 51: 166-176, 1969.

7. T. Sjostrand, "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," *Acta Medica Scandinavica*, 198: 687-699, 1947.

8. *Soupac Manual*, University of Illinois, 1969.

9. The Canadian Association for Health, Physical Education and Recreation, *The Physical Work Capacity of Canadian Children*, 1968.

10. The Canadian Association for Health, Physical Education and Recreation, *The Physical Fitness Performance and Work Capacity of Canadian Adults Aged 18 to 44 Years*, 1971.

11. H.G. Wahlund, "Determination of the Physical Working Capacity: A Physiological and Clinical Study with Special Reference to Standardization of Cardio-Pulmonary Functional Tests," *Acta Medica Scandinavica*, 132, Supplement 215: 9-86, 1948.

12. D. Watson, *Clin. Chim. Acta*, 5: 637, 1960.

13. N. Zöllner, *Dtsch. Med. Wschr.*, 84: 389, 1959.

CHAPTER IV

PRESENTATION AND DISCUSSION OF THE RESULTS

The aim of this study was to determine the effects of a 5 month program of physical activity (lacrosse) on selected physiological and anthropometric parameters of obese male adolescents. The results will be presented in three parts. The first part will examine anthropometric and skinfold measurement changes as a result of the program, the second cardio-respiratory measurements of a work capacity test and the third, hematological measurements. A discussion of the various results will follow their presentation. A summary of the statistical analysis is recorded in the appropriate appendix.

Anthropometric and Skinfold Measurements

The means, mean differences and significance of the F ratio (.05 and .01 levels) for the initial and final selected anthropometric and skinfold measurements of the experimental and control groups are recorded in Tables 6 and 7. Also included are the sample sizes for the initial and final measurements in both groups.

The analysis of variance revealed that statistically significant differences at the .05 level in chest depth, thigh girth, calf girth and sitting height existed between the experimental and control groups in the initial testing session. The difference between the initial means

Table 6

Anthropometric Measurements

Initial and Final Data

Variable	Units		Experimental Group Initial	Experimental Group Final	Experimental Group Diff	Control Group Initial	Control Group Final	Control Group Diff	F* Initial	F* Final
Height	in.	MN	66.7	67.5	.8	64.8	65.7	.8	-	-
		SD	1.6	1.3		3.0	2.8			
Weight	lbs.	MN	209.8	214.5	4.7	177.8	183.4	5.6	-	-
		SD	32.3	30.0		34.6	37.1			
Fat	%	MN	32.8	30.5	-2.3	33.4	28.7	-4.7	-	-
		SD	5.2	3.7		4.2	5.0			
Fat-Free Body Weight	lbs.	MN	139.7	147.7	8.0	116.9	129.1	12.2	.01	-
		SD	15.3	14.6		21.3	22.6			
Shoulder Width	in.	MN	16.5	18.2	1.7	16.0	16.4	.4	-	-
		SD	1.4	1.3		1.0	1.3			
Chest Breadth	in.	MN	13.9	14.2	.3	13.2	13.4	.2	-	-
		SD	1.0	1.0		1.0	1.4			
Hip Width	in.	MN	14.6	15.1	.5	14.2	14.2	0	-	-
		SD	1.4	1.3		1.0	1.5			
Knee Width	in.	MN	5.0	5.4	.4	5.3	5.1	-.2	-	-
		SD	.3	.3		1.2	.7			
Chest Depth	in.	MN	9.2	9.2	0	8.0	8.6	.6	.05	-
		SD	.7	.7		1.4	.8			

* $t \geq P < .05$ 4.38

$t \geq P < .01$ 8.18

Table 6 (continued)

Variable	Units		Experimental Group			Control Group			F	
			Initial	Final	Diff	Initial	Final	Diff	Initial	Final
Biceps Girth	in.	MN	13.3	14.0	.7	12.5	12.6	.1	-	-
		SD	1.3	1.3		1.0	1.2			
Chest Normal	in.	MN	42.9	43.4	.5	40.9	40.4	-.5	-	-
		SD	4.0	3.9		4.4	4.1			
Chest Inflated	in.	MN	43.7	44.1	.4	41.1	41.7	.6	-	-
		SD	3.9	3.6		3.7	4.0			
Chest Deflated	in.	MN	42.7	43.0	.3	40.0	40.3	.3	-	-
		SD	4.5	4.1		3.7	4.4			
Abdominal Girth	in.	MN	42.7	43.0	.3	39.8	39.7	-.1	-	-
		SD	5.2	4.6		4.0	4.2			
Gluteal Girth	in	MN	44.6	45.0	.4	41.5	42.7	1.2	-	-
		SD	3.9	3.4		3.8	4.7			
Thigh Girth	in.	MN	24.6	24.0	-.6	22.0	22.8	.8	.05	-
		SD	2.3	2.1		1.8	2.5			
Calf Girth	in.	MN	16.7	16.9	.2	15.2	15.6	.4	.05	-
		SD	1.2	1.1		1.3	1.2			
Ankle Girth	in.	MN	10.8	10.5	-.3	10.4	10.0	-.4	-	-
		SD	.5	.5		.5	.5			
Arm Span	in.	MN	69.6	70.3	.7	67.8	68.7	.9	-	-
		SD	2.2	1.9		5.2	4.6			
Sitting Height	in.	MN	34.2	34.9	.7	32.0	32.6	.5	.05	-
		SD	1.3	1.0		2.0	1.7			
N			11			10				
Age: $\bar{X}$			15.3			15.0				

Table 7

Skinfold Measurements

Initial and Final Data

Variable	Units		Experimental Group Initial	N	Final	N	Diff	Control Group Initial	N	Final	N	Diff	F* Initial	Final
Cheeks	mm	MN	19.0	11	19.7	11	.7	18.7	10	17.4	10	-1.3	-	-
		SD	3.7		3.2			4.0		2.8				
Midaxilla	mm	MN	30.2	11	28.5	11	-1.7	32.4	10	27.8	10	-4.6	-	-
		SD	7.5		4.2			6.3		7.4				
Chest	mm	MN	34.5	11	34.1	11	-.4	36.5	10	28.1	10	-8.4	-	-
		SD	6.2		4.7			4.3		7.7				
Abdomen	mm	MN	41.5	11	38.0	11	-3.5	37.2	10	32.4	10	-4.8	-	-
		SD	7.2		4.0			5.3		8.0				
Hips	mm	MN	38.3	11	34.6	11	-3.7	33.6	10	29.3	10	-4.3	-	-
		SD	5.4		4.3			7.0		7.4				
Subscapular	mm	MN	34.2	11	32.0	11	-2.2	31.8	10	26.6	10	-5.2	-	-
		SD	7.9		8.1			7.5		9.6				
Triceps	mm	MN	27.6	11	22.8	11	-4.8	26.0	10	22.8	10	-3.2	-	-
		SD	7.4		6.2			5.9		5.3				
Gluteals	mm	MN	41.8	10	40.9	10	-.9	43.4	9	39.3	8	-4.1	-	-
		SD	4.9		1.8			4.7		8.5				
Front Thigh	mm	MN	37.5	10	31.2	10	-6.3	34.9	10	30.9	9	-4.0	-	-
		SD	4.0		6.4			8.0		9.5				

* $t \geq P < .05$ 4.38
$t \geq P < .01$ 8.1

Table 7 (continued)

Variable	Units		Experimental Group					Control Group					F	
			Initial	N	Final	N	Diff	Initial	N	Final	N	Diff	Initial	Final
Rear Thigh	mm	MN	38.0	9	32.3	3	-5.7	37.3	3	27.4	1	-9.9	-	-
		SD	5.7		4.9			2.9		-				
Biceps	mm	MN	20.3	9	13.4	11	-6.9	13.3	8	11.7	8	-1.6	-	-
		SD	5.6		3.8			5.6		5.9				
Age: $\bar{X}$				15.3					15.0					

showed that the experimental group's chest depth exceeded that of the control group by 1.2 inches. Similarly, thigh girth, calf girth and sitting height were 2.6, 1.5 and 2.2 inches larger, respectively, in the experimental group than the control group.

The analysis of variance also indicated a significant statistical difference at the .01 level in fat-free body weight in the initial testing session, with the experimental group having a fat-free body weight 22.8 lbs. greater than that of the control group. No statistically significant differences between the two groups in other variables were revealed in this session.

In the final testing session, following the 5 month program, the analysis of covariance exposed no statistically significant differences between the experimental and control groups in fat-free body weight, chest depth, thigh girth, calf girth and sitting height.

The gain in weight by the experimental group during the 5 month program was 4.7 lbs. compared to 5.6 in the control group and the difference was not statistically significant. Likewise, the analysis of variance indicated no statistically significant differences between the two groups following the 5 month lacrosse program in height, shoulder width, chest breadth, hip width, knee width, chest normal, chest inflated, chest deflated, biceps girth and arm span.

The lack of a significant change in weight was accompanied by the non-significant change in abdominal, gluteal and ankle girths and percent fat.

The results of the skinfold measurements also produced non-statistically significant results, in turn reflected by a lack of change in percent fat in the two groups following the 5 month lacrosse program. The experimental group showed moderately smaller decreases in chest and rear thigh skinfolds and slightly smaller decreases in the midaxilla, chest, abdomen, hips, subscapular and gluteal skinfolds than the control group. The experimental group, however, suffered a moderately larger decrease in the biceps skinfold measurement and a slightly larger decrease in the triceps and front thigh skinfold measurements than the control group. The cheek skinfold measurement, however, increased in the experimental group by .7 mm and decreased by 1.3 mm in the control group.

Cardio-Respiratory Measurements of Work Capacity Test

Table 8 outlines the means, mean differences and significance of the F ratio (at .05 and .01 levels) for the initial and final cardio-respiratory measurements of the work capacity test. Sample sizes for all measurements in both groups are also listed.

Figure 2 illustrates the mean group heart rate response to sitting rest and ergometer exercise at 360, 720 and 1080 kpm/min in the initial and final testing sessions. The initial session resting heart rates of the two groups were not significantly different, as was again found following the 5 month program. At the initial testing session, the heart rates of the experimental and control groups during steady-state submaximal exercise at each workload were not significantly different. After 5 months, a highly significant difference was present at all three workloads; at the first workload (360 kpm/min), the heart rate of the experimental group lowered by 15.1 beats/min, while the decrease for the control group was 1.4 beats/min. At the second workload (720 kpm/min), the experimental group's heart rate was decreased by 17.5 beats/min and the control group's by 4.7 beats/min. At the third workload (1080 kpm/min), the decreases for the experimental and control groups were 23.3 and 14.5 beats/min, respectively.

In the initial and final testing sessions, the heart rate in both groups rose constantly from rest throughout

Table 8

Cardio-Respiratory Measurements of Work Capacity Test

Initial and Final Data

Variable	Units		Experimental Group Initial	N	Final	N	Diff	Control Group Initial	N	Final	N	Diff	F* Initial	Fi
Resting Heart Rate														
Rest 1	b/min	MN	97.8	11	91.8	11	-6.0	92.8	10	90.9	9	-1.9	-	-
		SD	13.6		6.3			7.8		13.8				
Rest 2	b/min	MN	96.4	10	92.5	11	-3.9	93.6	10	95.4	10	1.8	-	-
		SD	13.3		8.2			5.4		11.6				
Exercise Heart Rate														
1 KP	b/min	MN	128.4	11	113.3	11	-15.1	121.8	10	120.4	10	-1.4	-	.05
		SD	16.0		8.6			8.4		9.7				
2 KP	b/min	MN	139.0	10	121.5	11	-17.5	140.5	10	135.8	10	-4.7	-	.01
		SD	15.3		6.9			11.1		11.8				
3 KP	b/min	MN	154.9	10	131.6	10	-23.3	159.0	10	144.5	9	-14.5	-	.01
		SD	18.7		7.6			13.5		11.0				
Resting Oxygen Consumption														
Rest 1	L/minSTPD	MN	.51	11	.42	11	.09	.30	10	.40	9	.1	.05	-
		SD	.20		.08			.05		.04				
Rest 2	L/minSTPD	MN	.48	11	.47	11	.01	.30	8	.41	10	.1	-	-
		SD	.24		.08			.04		.06				

* $t \geq P < .05$ 4.38
$t \geq P < .01$ 8.18

Table 8 (continued)

Variable	Units		Experimental Group					Control Group					F	
			Initial	N	Final	N	Diff	Initial	N	Final	N	Diff	Initial	Final
Exercise Oxygen Consumption														
1 KP	L/min STPD	MN	1.04	11	.99	11	-.05	.86	9	1.08	10	.22	.05	-
		SD	.20		.18			.13		.15				
2 KP	L/min STPD	MN	1.3	10	1.21	11	-.09	1.18	8	1.32	10	.14	-	-
		SD	.37		.18			.17		.16				
3 KP	L/min STPD	MN	1.68	10	1.59	11	-.09	1.44	10	1.55	9	.11	-	-
		SD	.27		.37			.23		.17				
Recovery Oxygen Consumption	L/min STPD	MN	.59	7	.57	11	-.02	.45	8	.51	9	.06	.05	-
		SD	.12		.1			.07		.07				
Resting Respiratory Quotient														
Rest 1		MN	.78	11	.77	11	-.01	.92	10	.83	9	-.09	-	-
		SD	.13		.08			.15		.14				
Rest 2		MN	.81	11	.78	11	-.03	.88	8	.82	10	-.06	-	-
		SD	.13		.05			.13		.13				
Exercise Respiratory Quotient														
1 KP		MN	.86	11	.8	11	-.06	.9	9	.84	10	-.06	-	-
		SD	.1		.06			.2		.14				
2 KP		MN	.89	10	.86	11	-.03	.95	8	.95	10	0	-	-
		SD	.08		.06			.09		.12				

Table 8 (continued)

Variable	Units		Experimental Group					Control Group					F	
			Initial	N	Final	N	Diff	Initial	N	Final	N	Diff	Initial	Fina
3 KP		MN	.94	10	.89	11	-.06	.99	10	1.01	9	.02	-	.05
		SD	.05		.06			.09		.17				
Recovery Respiratory Quotient		MN	.96	7	.9	11	.06	1.06	8	.96	10	-.1	-	-
		SD	.07		.03			.13		.16				
Resting Oxygen Consumption/ Body Weight														
Rest 1	ml/kg/min	MN	5.2	11	4.4	11	-.8	3.9	10	5.1	9	1.2	-	-
		SD	1.8		1.0			.7		.9				
Rest 2	ml/kg/min	MN	5.1	11	5.0	11	-.1	3.7	8	5.1	10	1.4	-	-
		SD	2.7		1.0			.9		1.3				
Exercise Oxygen Consumption/ Body Weight														
1 KP	ml/kg/min	MN	10.8	11	10.2	11	-.6	10.6	9	13.7	10	3.1	-	.05
		SD	2.1		1.2			1.6		4.4				
2 KP	ml/kg/min	MN	13.7	10	12.6	11	-1.1	14.6	8	16.7	10	2.1	-	.05
		SD	3.1		1.7			2.5		4.9				
3KP	ml/kg/min	MN	17.8	10	16.4	11	-1.4	18.6	10	19.9	9	1.3	-	-
		SD	2.8		3.0			5.2		4.6				

Table 8 (continued)

Variable	Units		Experimental Group Initial	N	Final	N	Diff	Control Group Initial	N	Final	N	Diff	F Initial	Fina
Recovery Oxygen Consumption/ Body Weight	ml/kg/min	MN	6.2	7	5.9	11	-.3	6.1	8	6.4	10	.3	-	-
		SD	.8		.8			.9		.9				
Resting Oxygen Pulse Rest 1	ml/beat	MN	5.2	11	4.6	11	-.6	3.3	10	4.5	9	1.2	.05	-
		SD	2.2		.8			.6		.6				
Rest 2	ml/beat	MN	5.3	10	5.1	11	-.2	3.3	8	4.3	10	1.0	-	.05
		SD	3.2		.7			.5		.7				
Exercise Oxygen Pulse 1 KP	ml/beat	MN	8.3	11	8.8	11	.5	7.3	9	9.1	10	1.8	-	-
		SD	2.0		1.3			.8		1.7				
2 KP	ml/beat	MN	9.2	11	10.1	10	.9	8.6	8	9.9	10	1.3	-	-
		SD	2.3		1.5			1.5		1.8				
3 KP	ml/beat	MN	11.0	10	12.1	11	1.1	9.1	10	10.9	9	1.8	-	-
		SD	2.5		2.5			1.5		1.5				

* using analysis of covariance

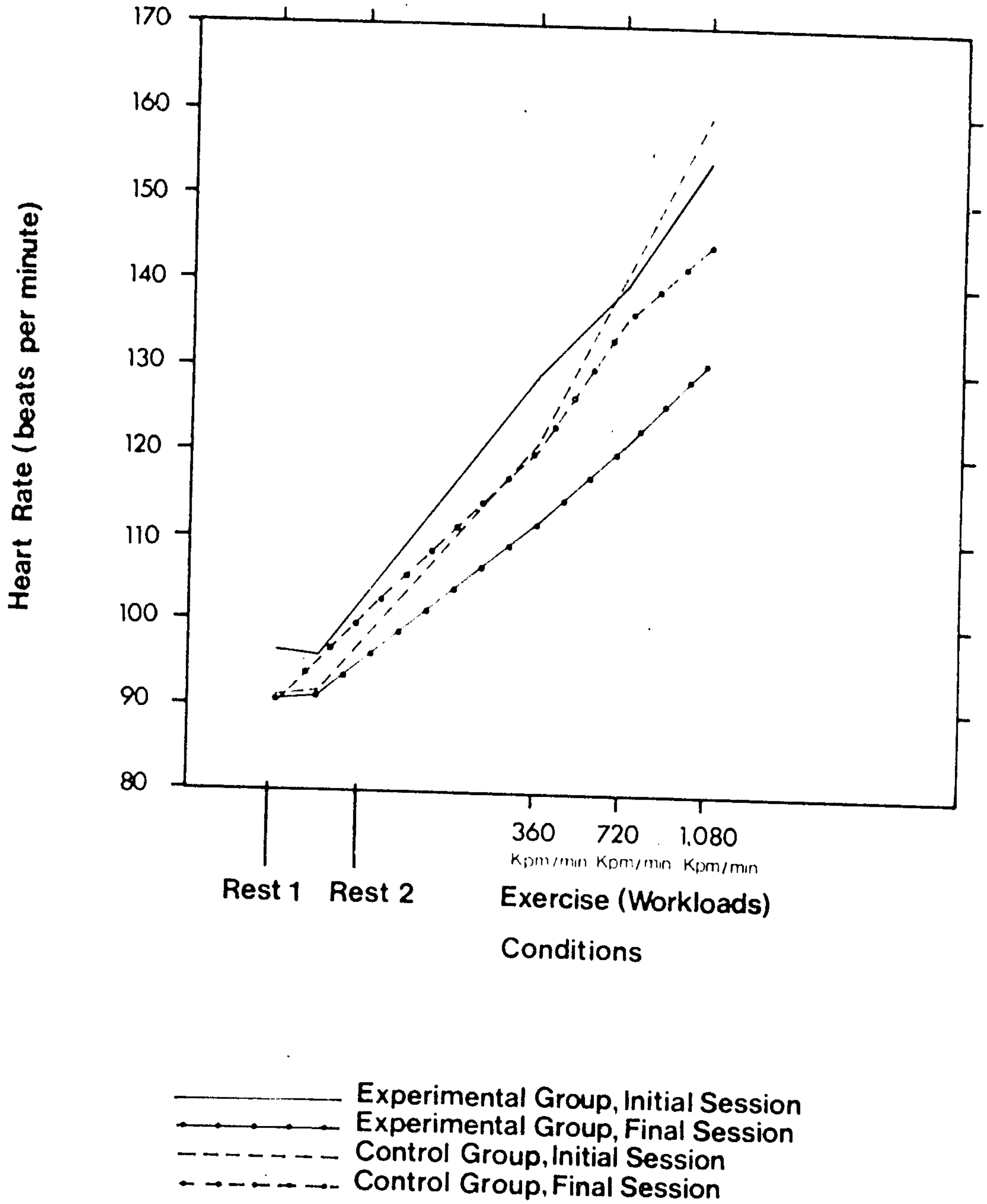

Figure 2

Initial and Final Session Measurements of Heart Rate During Exercise

exercise in response to increasingly higher workloads (Figure 2). In the final session, it can be seen that the rise in heart rate for the experimental group was at a significantly lower level than that for the control group.

Figure 3 illustrates the mean oxygen consumption, expressed in 1/min STPD, of the experimental and control groups during sitting rest and ergometer exercise in the initial and final testing sessions. In these sessions, the workload - $\dot{V}O_2$ relationship was approximately linear for both groups from rest to the end of the third workload (1080 kpm/min). At rest 1, the initial oxygen consumptions of the two groups were significantly different; at rest 2, they were not. After 5 months, the resting oxygen consumption of the experimental and control groups showed no statistically significant difference.

Prior to commencement of the program, the analysis of variance revealed a statistically significant difference between the two groups in oxygen consumption at the first workload and for the 5 minute recovery period, without a significant difference at the second and third workloads. After 5 months, the oxygen consumptions of the two groups for the three workloads and the 5 minute recovery period were not significantly different. In addition, recovery measurements of oxygen consumption did not reach resting values in the 5 minute recovery period for any group in either session.

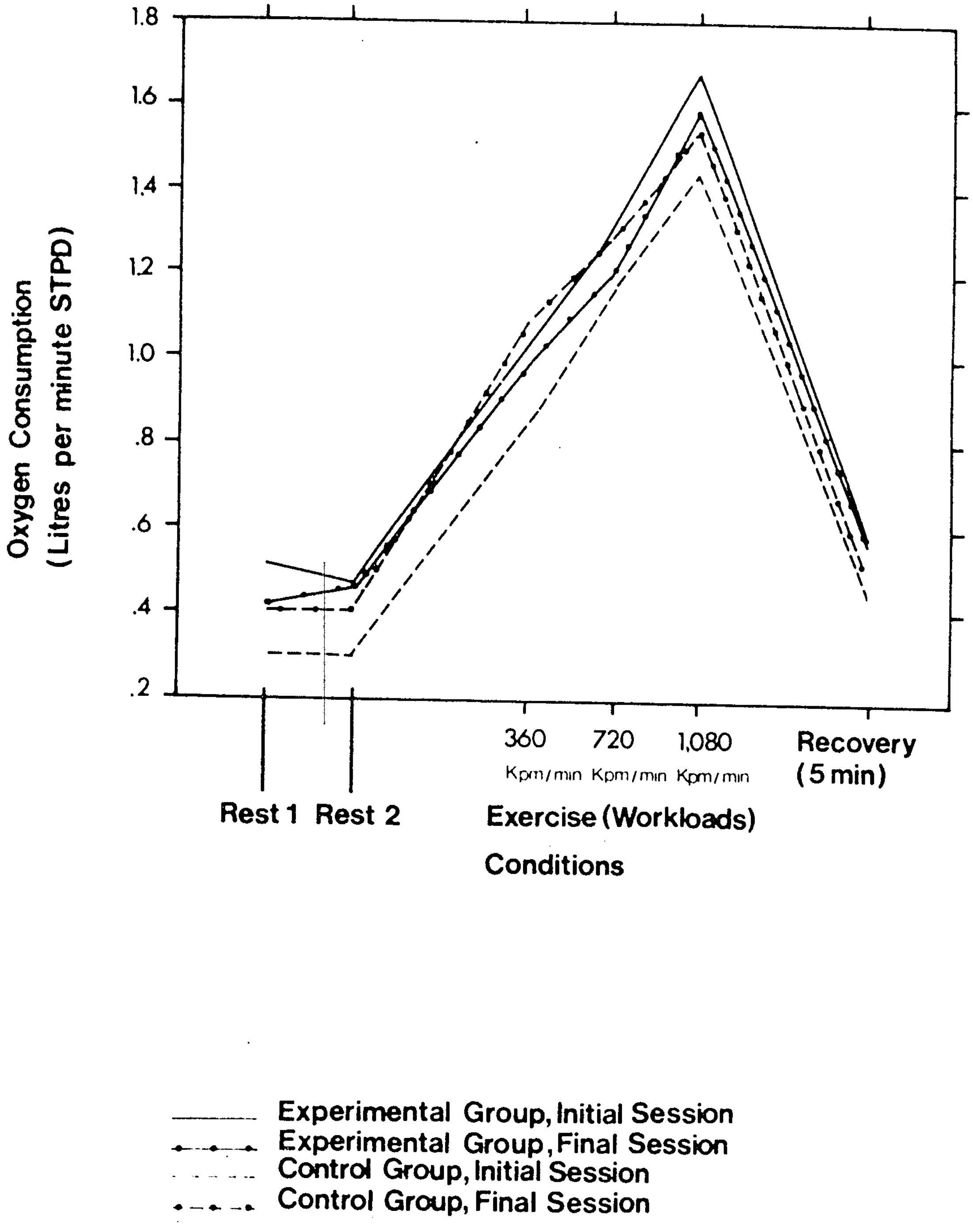

Figure 3

Initial and Final Session Measurements of Oxygen Consumption (L/min. STPD) During Exercise.

Figure 4 illustrates the mean oxygen consumption divided by body weight (ml/kg/min) of the experimental and control groups in the work capacity test. Again, the workload -$\dot{V}O_2$ relationship was approximately linear for both groups from rest to the end of the third workload (1080 kpm/min). Except for the oxygen consumptions at the first and second workloads after 5 months, the results were not statistically significant. At the first workload, the oxygen consumption of the experimental group dropped .6 ml/kg/min while the control group's rose 3.1 ml/kg/min; at the second workload, oxygen consumption decreased 1.1 ml/kg/min in the experimental group and increased 2.1 ml/kg/min in the control group after 5 months. During the 5 minute recovery period, oxygen consumption decreased linearly to above-resting values in each group.

The respiratory quotients obtained during sitting rest, ergometer exercise at 360, 720 and 1080 kpm/min and the average RQ for the 5 minute recovery period are illustrated in Figure 5. In the initial testing session, statistical analysis by the analysis of variance indicated no significant differences in RQ between the groups at rest, during exercise and recovery. After 5 months, the RQ was not significantly different between the two groups at rest, during exercise at 360 and 720 kpm/min and recovery. At 1080 kpm/min, however, the experimental group's RQ in the final session had lowered in comparison to the RQ in the initial session (from .94 to

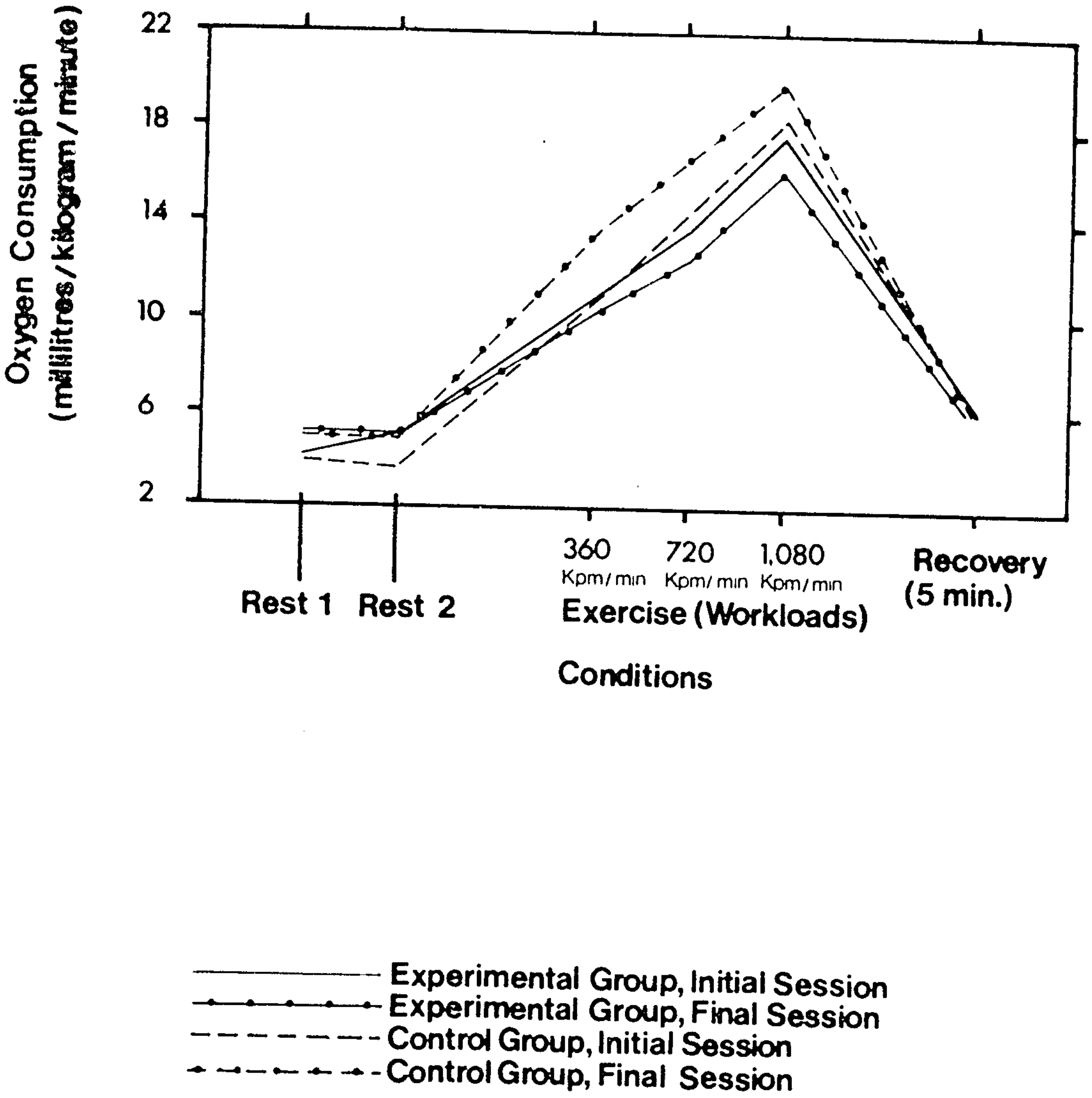

Figure 4

Initial and Final Session Measurements of Oxygen Consumption (ml/kg/min) During Exercise

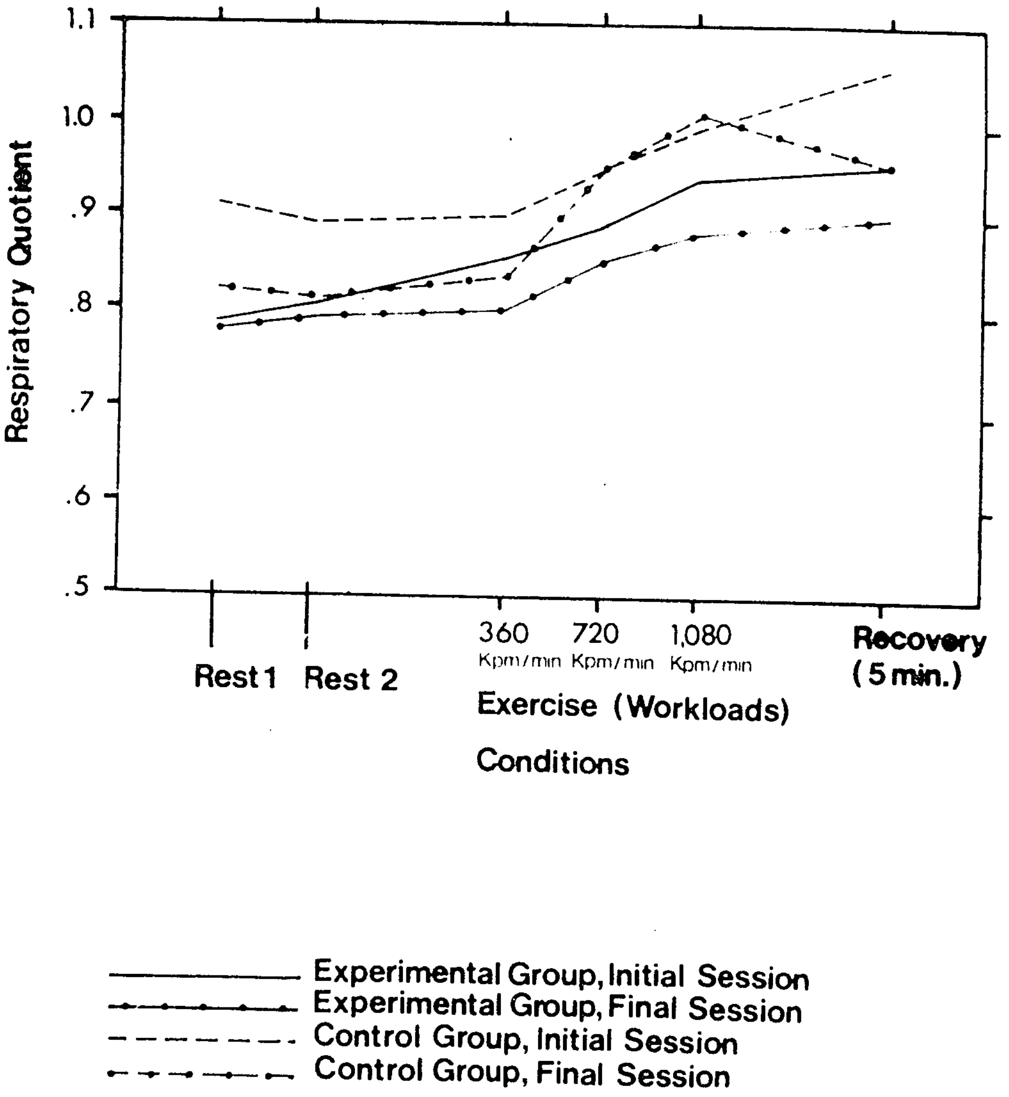

Figure 5

Initial and Final Session Measurements of Respiratory Quotient During Exercise

.88), while the control group's had increased (from .99 to 1.01), resulting in a statistically significant difference. In both sessions for both groups, the RQ at rest maintained a value between .78 and .88. During exercise, it tended to increase steadily upwards with increasing workloads, reaching values of .94 and .88 at the highest workload in the initial and final sessions, respectively, for the experimental group and .99 and 1.01, similarly in the control group. The average RQ for the 5 minute recovery period was higher in the experimental group in both sessions than the same value at 1080 kpm/min; similarly, in the control group, it was higher in the initial session (reaching 1.06) but lower in the final session.

Figure 6 illustrates the mean oxygen pulse of the experimental and control groups at rest and during ergometer exercise at 360, 720 and 1080 kpm/min. In the initial testing session, a statistically significant difference between the groups was revealed in the first resting measurement of oxygen pulse, which, however, was not found in the second resting measurement. No other significant differences between the two groups using the analysis of variance method were indicated in this session during exercise.

The oxygen pulse increased during exercise in both testing sessions for both groups, the highest values occurring at the highest workload of 1080 kpm/min. After 5 months, a statistically significant difference occurred in the second

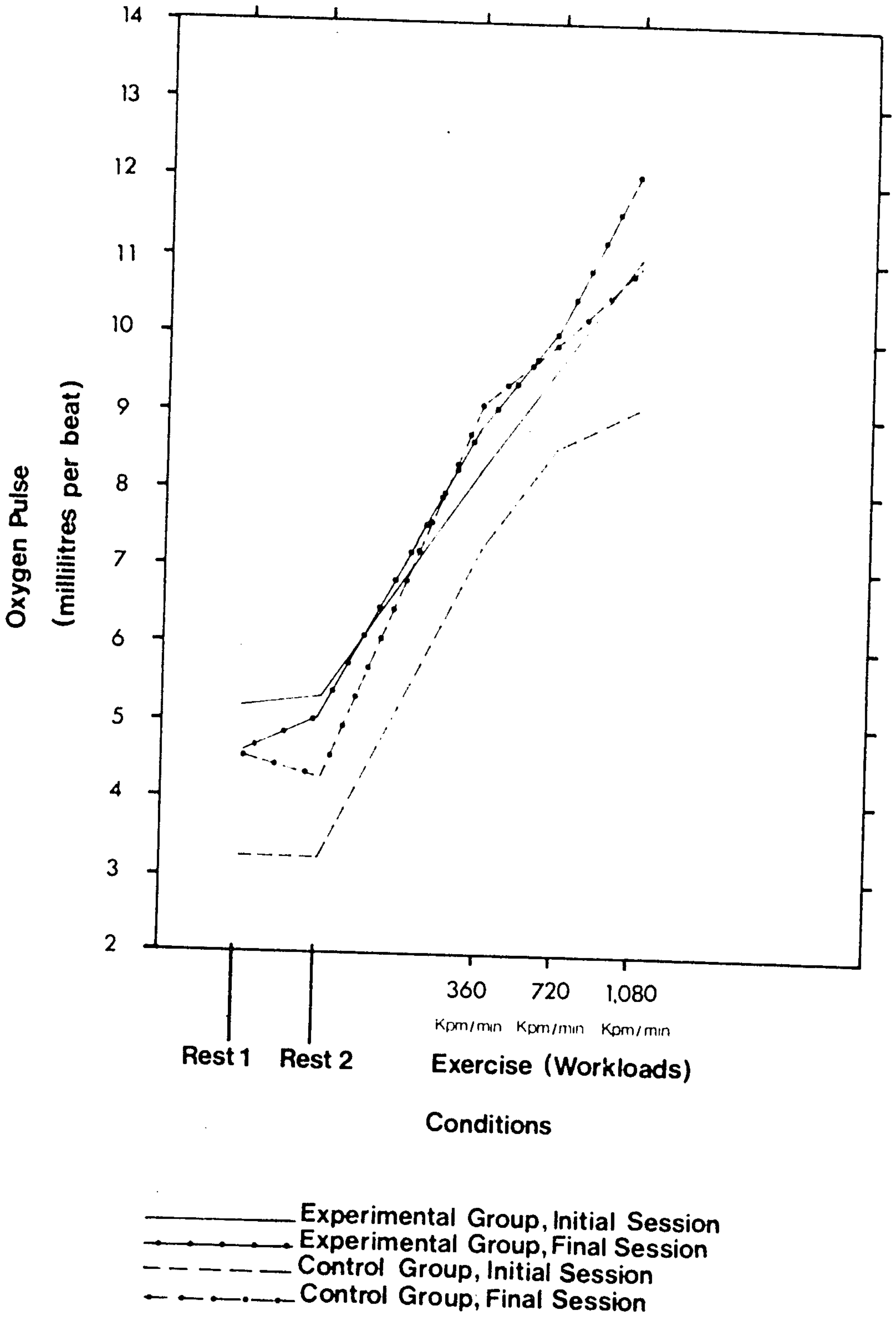

Figure 6

Initial and Final Session Measurements of Oxygen Pulse During Exercise resting measurement; the mean oxygen pulse of the experimental group decreased .2 ml/beat while that of the control group reached 1.0 ml/beat. Although the increase in oxygen pulse at each workload for the experimental group was less than that for the control group after 5 months, the results were statistically non-significant.

Hematological Measurements

In Table 9 are presented the means, mean differences and any significance of the F ratio for the initial and final hematological measurements (hemoglobin, hematocrit, cholesterol and thyroxine) of the experimental and control groups. Included also for each variable is sample size. The analysis of variance revealed no significant differences between the groups in the four hematological variables in the initial or final testing sessions. Thus, the 5 month lacrosse program did not significantly affect hemoglobin, hematocrit, cholesterol and thyroxine levels in the experimental group.

Discussion

The results of the anthropometric and skinfold measurements in this study indicated that the experimental group, after a 5 month lacrosse program, suffered insignificant changes in body weight.

Table 9

Hematological Measurements

Initial and Final Data

Variable	Units		Initial	N	Final	N	Diff	Initial	N	Final	N	Diff	F* Initial	F* Final
Hemoglobin	gms %	MN	15.1	11	15.4	11	.3	14.3	10	14.9	10	.6	-	-
		SD	.8		.9			.2		1.2				
Hematocrit	vol %	MN	42.0	11	43.0	11	1.0	40.4	10	41.3	10	.9	-	-
		SD	2.6		2.8			2.8		2.7				
Cholesterol	mg %	MN	165.0	11	149.6	11	-15.4	182.8	10	162.9	10	-19.9	-	-
		SD	25.4		25.8			13.8		17.9				
Thyroxine	μgm	MN	6.4	11	3.7	11	-2.7	6.9	10	3.8	10	-3.1	-	-
		SD	1.3		1.1			1.5		.6				

* t≥ P< .05 4.38

t≥ P< .01 8.18

indicates that major changes in body weight and composition as a result of vigorous exercise involve a decrease in fat and an increase in muscle mass with the variations in total body weight dependent upon the proportional change in these two components. In this study, the non-significant change in body weight was accompanied by a lack of improvement (i.e. a decrease) in percent fat. The result for the latter variable was in turn reflected by the non-significant change in the final testing session in the skinfold measurements (cheeks, midaxilla, chest, abdomen, hips, subscapular, triceps, gluteals, front thigh, rear thigh, biceps), girths (abdominal gluteal, calf,thigh, ankle) and other measurements - height, fat-free body weight, shoulder width, chest breadth, hip width, chest depth, chest normal, chest inflated, chest deflated, biceps girth, arm span and sitting height.

It is evident from the anthropometric and skinfold results that the 5 month lacrosse program held 1 1/4 hours, two times per week, was not of high enough energy cost to reduce body weight and percent fat in the experimental group. It has been reported that high energy cost programs such as running (15, 32, 36), swimming (34) and skiing (34) can reduce body weight and percent fat in non-obese adult men, while low energy cost programs have little or no effect (9, 34). The questions of how much exercise, how often and of what duration is required to change body weight and composition have been the subject of many investigations (19,

20, 28, 35). Studies probing these changes in the obese have been carried out more recently. Dempsey's (16) program for 18 to 28 year old men consisted of 8 weeks daily training, then 5 weeks normal or decreased activity followed by 8 weeks daily training again; total body fat, subcutaneous fat, and body weight decreased with an increase in fat-free body weight, presumably muscle mass. Sprynarova and Parizkova's (39) 7 week program of dietary restriction and daily physical exercise and walking resulted in a decrease in body weight, adipose tissue and lean body mass for 11-year old boys. Obese adolescent boys (13-14 years) succeeded in gaining less weight than the control group in Christakis _et al.'s_ (12) program of nutrition education, and classes in body-building exercises, weight lifting and general conditioning exercises twice a week for 18 months. Knowlton and Weber (28) similarly found a significant reduction in percent fat and body weight of markedly obese middle-aged men who carried out 10 weeks of progressive training combined with dietary restriction. It would appear from these studies that the lacrosse program of this study, without any concurrent dietary control or restriction in the experimental group, lacked enough sessions per week and was not of sufficient length (that is, more than 5 months). Assuming that the loss of fat is achieved solely through the creation of a negative caloric balance, the sum of the energy cost of the program and nil dietary restriction was not great enough to result in a negative caloric balance.

In considering the energy cost of the program, several factors are of importance. Firstly, the lacrosse program was chosen as the experimental treatment of this study mainly with two conditions in mind - most important, it would allow for good social interaction (an interest of another party in the investigation) and it uses all major muscle groups. Secondly, the range of percent fat in the initial testing session for the experimental group was 23 to 40 with those above 30 percent that, according to Dempsey (17), can be classified as grossly obese. Although all subjects in this group were exposed to the same program, not all activity in each session was carried out with respect to time and content in the same manner. Low skill levels were prevalent at the beginning of the program and, differences in the rate of learning, motivation, degree of movement (with respect to fat present) and actual attendance were very prevalent; thus, it seems not unreasonable to expect wide differences in energy expenditure and, coupled with a lack of dietary restriction, the subsequent lack of change in anthropometric and skinfold measurements is not unexpected.

The work capacity test used in this study incorporated an ergometer ride set at moderate workloads of 360, 720 and 1080 kpm/min in order not to unduly stress the obese subjects. It was considered important that the subjects be able to complete these workloads and that if they were too severe or exhausting, motivation would play a negative factor during the ride and influence a subject's return to the final testing session following the program. The cardio-respiratory responses, however, indicated that the workloads were moderately and not severely, stressing. It must be considered too that leg strength is an important component in the ability to attain higher workloads on the bicycle ergometer (30) and for the obese subject it is to his advantage.

The discussion of the results for the cardio-respiratory measurements of the work capacity test is somewhat complicated by the inconsistency of the results of the data, a condition Durnin <u>et al</u>. (18) point out, frequently encountered in human experiments.

Mean heart rate measurements during sitting rest in the experimental group showed no significant changes as a result of the program. It is noted, however, that the mean heart rates of both groups at rest in both sessions were within the normal ranges of values (24). During the ergometer exercise, which can be classified as steady-state and submaximal, a training effect, as a result of the 5 month program, was dominant in the experimental group at all phases of exertion. That is, the experimental group was able to work at 360, 720 and 1080 kpm/min at lower heart rates in the final session than the initial session. Consequently, this group exhibited smaller increases in heart rate from load to load in the final session that the control group. Brouha (6) has indicated that one of the effects of training is to increase the stroke volume so that, in the trained individual, adequate cardiac output is obtained at a lower pulse frequency than before training. Assuming that oxygen pulse is a good index of stroke volume (3, 26) no significant improvements (i.e. an increase) in oxygen pulse occurred in this study during exercise at any workload. Thus, some inconsistency of the data reveals itself here.

The 5 month lacrosse program had an insignificant effect upon the mean resting values of oxygen consumption (VO_2 1/min STPD) in the experimental group. Similarly absolute VO_2 during steady-state submaximal exercise at 360, 720 and1080 kpm/min and the average VO_2 for the 5 minute recovery period were not significantly changed by the program. Although, initially, a higher VO_2 at 360 kpm/min manifested itself in the experimental group, as mentioned, no significant difference existed after 5 months. It is reported (4,11 ,30 , 41, 42) that obese subjects during the same rest and exercise conditions as non-obese subjects have a greater absolute VO_2. Alexander (1) found that treadmill exercise studies at varying grades to assess the oxygen requirement of normal and very obese subjects for the same exercise task demonstrated a greater oxygen uptake 1/min in the obese than normal subjects. Cureton (13) reasons that a large man will require more oxygen than a small man. In the obese, the excess fat increases the oxygen cost of work and therefore the cardiovascular load during submaximal work (8).

In this study, it seems of interest to compare the resting values of VO_2 1/min, and VO_2 1/min during steady - state submaximal exercise at the three workloads to those values obtained similarly for non-obese or so-called normal subjects. However, the data available for non-obese adolescents, in the age group of 14 to 17 years old, is not numerous. Knuttgen (29) did, however, investigate aerobic capacity of 15 to 18 year old boys; a mean resting value of VO_2 1/min while sitting on the bicycle ergometer was reported to be .275 + .035 1/min STPD, which, as noted, is much smaller than the mean resting VO_2 1/min (experimental I: .51 ± .20, .48 ± .24, experimental II: .42 ± .08, .47 ± .08; control I: 30 ± .05, 30 ± .04; control II: .40 ± .04, .41 ± .06) obtained in this study under the same condition, as would be expected. No further comparison data, however, was available from the same study.

When VO_2 was expressed in ml/kg/min, again resting values after 5 months were not significantly different. "When weight is divided out, the relative efficiency (the rate at which oxygen can be supplied for each kilogram of body weight) is more clearly reflected and is not just a reflection of the body weight," Cureton (13) states. That is, the VO_2 ml/kg/min measure "...reflects the oxygen that is used in the tissues per kilogram of body weight"(13). Buskirk (7) comments that the ability to deliver oxygen to working muscles and its rate of utilization by muscle may be fairly normal or reduced in obese subjects depending on their sex, age and past exercise history. On a per-kilogram basis, however, the obese subject's aerobic capacity is definitely reduced as body weight must usually be transported in the performance of hard work. As Moody (30) states, "...obesity tissue contributes little to increased oxygen utilization during exercise and in effect is relatively inert when considered on an aerobic basis". Many investigators (7, 30, 42) similarly, have reported the VO_2 ml/kg/min of obese subjects to be lower at rest and under the same exercise conditions as non-obese subjects. Due to lack of comparable age and exercise conditions it is not possible to compare the VO_2 ml/kg/min of the obese subjects of this study during sitting rest and steady-state submaximal exercise.

Following the 5 month program, the experimental group significantly required less VO_2 ml/kg/min at 360 and 720 kpm/min than prior to the program. Assuming that oxygen intake must be adequate to meet oxygen requirement, it would seem that as a result of the lacrosse program, the oxygen requirement for these workloads decreased, thereby resulting in less oxygen uptake. Morehouse and Miller (31) have indicated that such a decrease may be due to more efficient use of muscles, elimination of extraneous movements and greater mechanical efficiency of muscles. The training effect, however, did not elicit itself at 1080 kpm/min or during recovery, again revealing inconsistency of data.

The mean respiratory quotient during sitting rest, submaximal steady-state exercise at 360 and 720 kpm/min, and the average mean respiratory quotient for the 5 minute recovery period were not significantly changed by the 5 month lacrosse program. At the greatest workload, 1080 kpm/min, however, the experimental group's RQ (.88) was significantly lower than the control group's (1.01) in the final testing session. It is evident from the mean RQ values obtained during rest and submaximal exercise up to the end of 720 kpm/min, in the initial and final testing sessions, that both groups utilized primarily fat as their energy source. At 1080 kpm/min, in the final testing session, the control group's RQ of 1.01 was indicative of carbohydrate utilization while the experimental group's RQ of .88 indicated primarily fat utilization. The use of fat for muscular work is well documented. The resting muscle in man almost exclusively consumes fat (2) the main substrate for fat utilization being free fatty acid (FFA) mobilized from fat depots and transported through the blood and triglycerides and stored in the muscles. Strang (40) has cited evidence that indicates that fasting respiratory quotients in obese persons have a tendency to be lower than in normals and according to the usual interpretation that means the obese are burning more fat than normals. The FFA uptake and oxidation by muscles increases during work (23, 10, 11). The increase of the RQ with severity of work is much more pronounced in poorly trained subjects (38); in this study the RQ increased steadily upwards with increasing workloads in both groups in the initial and final testing sessions, an indication of essentially no training effect in the final testing session. Christensen and Hansen as reported by Simonson (38) have suggested that the use of carbohydrate depends on the oxygen supply of the working muscles; the better the oxygen supply, the lower the carbohydrate utilization which likewise agrees with the improvement of capillarity by training. Thus, training tends to increase fat utilization during work. It would seem, therefore, that in this study any training effect produced in the experimental group by the 5 month lacrosse program was not elicited until performing steady-state submaximal exercise at a 1080 kpm/min workload. The experimental group was significantly able to utilize fat primarily for energy, while the control group utilized carbohydrate.

The average mean RQ for the 5 minute recovery period increased from the mean RQ value at 1080 kpm/min in the experimental group in the initial and final testing session and in the control group in the initial testing session. Karpovich (25) comments, however, that if exercise is of short duration, or long but not exhaustive, the RQ will usually fall following exercise. It is difficult to interpret the average mean RQ for the recovery period because it is not a true reflection of the RQ immediately following exercise and every minute thereafter.

With respect to oxygen pulse, it was seen that the experimental group had a significantly higher measurement at rest 1 prior to the program compared to the control group, with no significant difference existing after 5 months. At rest 2, initially, no differences between the groups were revealed, however, after 5 months, the experimental group's mean oxygen pulse was lower and the control group's increased, resulting in a significant difference. During ergometer exercise, no significant changes in oxygen pulse occurred at each workload for the experimental group after 5 months, thus indicative of a lack of training effect. As was found in some other data of the study, a lack of consistency presented itself in these measurements also. The oxygen pulse is often regarded as a measure of good adaptation of the circulatory system to the load, expressing a relation between the consumed oxygen and the respective heart rate (37). Karpovich (26) has indicated that it increases rapidly with acceleration of the heart, and in most cases reaches its maximum value of 11 to 17 cc at heart rates of 130 to 140 beats per minute. In examining the data of this study, and assuming that oxygen pulse is a reliable index of stroke volume (3, 26), it can be seen that the stroke volume of each group in both sessions increased with each work load, but did not reach their limit in output per beat at workloads of 360, 720 and 1080 kpm/min. Moody et al. (30) and Turell et al. (41) are in agreement that the oxygen pulse of obese compared to non-obese subjects is higher under similar resting and exercise conditions. Because of the lack of normal subjects in this study, such a comparison cannot be made at this time.

Essentially, blood analysis prior to and following the lacrosse program revealed that the four hematological variables - hematocrit, hemoglobin, cholesterol and thyroxine - were not significantly changed in the experimental group. It is interesting to note that the serum cholesterol values for both groups in both sessions were above-normal, according to the NIH Centre values for the age group 1 to 20 years. This is not always the case for those with obesity, as has been mentioned previously. In accordance with Cureton's recommendations (14) for reducing cholesterol levels, and the fact that any change in cholesterol is related to the metabolic and fitness changes brought about by training (14), then the lack of any change in cholesterol levels in the experimental group in this study was not unexpected. Serum thyroxine values, similarly, in both groups for both sessions were within the normal range of values (33), a finding which supports Hung _et al.'s_ (22) finding of normal thyroxine metabolism in obese adolescents. Hematocrit and hemoglobin values, too, were within the normal ranges (21, 5) in both groups prior to and following the program.

REFERENCES

Chapter IV

1. J.K. Alexander, "Obesity and Cardiac Performance," American Journal of Cardiology, 14: 860-865, 1969.
2. R. Andres, G. Cader and K.L. Zierler, "The Quantitatively Minor Role of Carbohydrate in Oxidative Metabolism by Skeletal Muscle in Intact Man in the Basal State. Measurements of O_2 and Glucose Uptake and CO_2 and Lactate Production in the Forearm," Journal of Clinical Investigation, 35: 671-682, 1956.
3. I. Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, 49: 1, 1960.
4. I. Astrand, P.-O. Astrand and A. Stunkard, "Oxygen Intake of Obese Individuals During Work on a Bicycle Ergometer," Acta Physiologica Scandinavica, 50: 294-299, 1960.
5. P.-O. Astrand and K. Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 107.
6. L.A. Brouha, "Effect of Work on the Heart," Work and the Heart, F.F. Rosenbaum and E.L. Belknap, editors (New York: Paul B. Hoeber, Inc., 1959), p. 183.
7. E.R. Buskirk, "Increasing Energy Expenditure: The Role of Exercise," Obesity, N. Wilson, editor (Philadelphia: F.A. Davis Co., 1969), pp. 163-176.
8. E. Buskirk and H.L. Taylor, "Maximal Oxygen Intake and its Relation to Body Composition, with Special Reference to Chronic Physical Activity and Obesity," Journal of Applied Physiology, 11: 72-78, 1957.
9. D.E. Campbell, "Influence of Several Physical Activities on Serum Cholesterol Concentrations in Young Men," Journal of Lipid Research, 6: 478-480, 1965.
10. L.A. Carlson, "Lipid Metabolism and Muscular Work," Federation Proceedings, 26; 1755-1759, 1967.
11. L.A. Carlson, "Plasma Lipids and Lipoproteins and Tissue Lipids during Exercise," Nutrition and Physical Activity, G. Blix, editor (Uppsala: Almquist and Wiksells, 1967), pp. 16-31.

12. G. Christakis, S. Sajecki, R.W. Hillman, E. Miller, S. Blumenthal and M. Archer, "Effect of a Combined Nutrition Education and Physical Fitness Program on the Weight Status of Obese High School Boys," Federation Proceedings, 25: 15-19, 1966.

13. T.K. Cureton, Physical Fitness of Champion Athletes (Urbana: University of Illinois Press, 1951), p. 329-330.

14. T.K. Cureton, The Physiological Effects of Exercise Programs on Adults (Springfield: C.C. Thomas, 1969), pp. 52-55.

15. T.K. Cureton and E.E. Phillips, "Physical Fitness Changes in Middle-Aged Men Attributable to Equal Eight-Week Periods of Training, Non-Training and Retraining," Journal of Sports Medicine and Physical Fitness, 4: 87-93, 1964.

16. J.A. Dempsey, "Anthropometric Observations on Obese and Non-Obese Young Men Undergoing a Program of Vigorous Muscular Exercise," Research Quarterly, 35: 276-287, 1964.

17. J.A. Dempsey, W. Reddan, B. Balke and J. Rankin "Work Capacity Determinants and Physiologic Cost of Weight - Supported Work in Obesity," Journal of Applied Physiology, 21: 1815-1820, 1966.

18. J.V.G.A. Durnin, J.M. Brockway and H. W. Whitcher, "Effects of a Short Period of Training of Varying Severity on Some Measurements of Physical Fitness," Journal of Applied Physiology, 15: 161-165, 1960.

19. H.P. Elder, "Effects of Training on Middle-Aged Men," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 133-138.

20. B.D. Franks, "Effects of Different Types and Amounts of Training on Selected Fitness Measures," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 139-160.

21. W.R. Faulkner and J.W. King ,(eds.), Manual of Clinical Laboratory Procedure (Cleveland: The Chemical Rubber Company, 1970), p. 1125.

22. W. Hung, G.P. Gancayco and F.P. Heald, "Thyroxine Metabolism in Obese Adolescent Males," Pediatrics, 36; 877-881, 1965.

23. B. Issekutz,Jr., M.I. Miller, P. Paul and K. Rodahl, "Source of Fat Oxidation in Exercising Dogs," American Journal of Physiology, 207: 583, 1964.

24. P.V. Karpovich and W.E. Sinning, Physiology of Muscular Activity, 7th edition (Philadelphia: W.B. Saunders Company, 1971), p. 198.

25. Karpovich, pp. 82-83.

26. Karpovich, p. 169.

27. A. Keys, "Body Composition and its Change with Age and Diet," Weight Control, A. Keys, editor (Iowa: Iowa State College Press, 1955), pp. 18-28.

28. R.G. Knowlton and H. Weber, "Effects of Progressive Endurance Training and Voluntary Dietary Restriction on Metabolic and Cardiorespiratory Adaptations in Markedly Obese Subjects," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 179-194.

29. H.G. Knuttgen, "Aerobic Capacity of Adolescents," Journal of Applied Physiology, 22: 655-658, 1967.

30. D.L. Moody, J. Kollias and E.R. Buskirk, "Evaluation of Aerobic Capacity in Lean and Obese Women with Four Test Procedures," Journal of Sports Medicine and Physical Fitness, 9: 1-9, 1969.

31. L.E. Morehouse and A.T. Miller, Physiology of Exercise, 5th edition (St. Louis: The C.V. Mosby Company, 1967), p. 184.

32. J. Naughton and F. Nagle "Peak Oxygen Intake during Physical Fitness Program for Middle-Aged Men," Journal of the American Medical Association, 191: 899-901, 1965.

33. S. Passen and R. von Saleski, "A Semiautomated Method which Does Not Require Digestion for the Determination of Serum Thyroxine Iodine (T_4)," American Journal of Clinical Pathology, 51: 168-176, 1969.

34. M.L. Pollock, T.K. Cureton and L. Greninger, "Effects of Frequency of Training on Working Capacity, Cardiovascular Function, and Body Composition of Adult Men," Medicine and Science in Sports, 1: 70-74, 1969.

35. M.L. Pollock, J. Tiffany, L. Gettman, R. Janeway and H.B. Lofland, "Effects of Frequency of Training on Serum Lipids, Cardiovascular Function and Body Composition," Exercise and Fitness (Chicago: The Athletic Institute, 1969), pp. 161-178.

36. P.M. Ribsl, "Changes in Maximal Oxygen Intake with Training in Middle-Aged Men," Abstracts of Research Papers (Aahper 1967 Convention), p. 13.

37. V. Seliger and V. Zelenka, "Physical Fitness of Czech Children at 12 and 15 Years of Age," Acta Universitatis Carolinae Gynica, 5, 1970.

38. E. Simonson, "Nutrition and Work Performance," Physiology of Work Capacity and Fatigue, E. Simonson, editor (Illinois: C.C. Thomas, 1971), p. 367.

39. S. Sprynarova and J. Parizkova, "Changes in the Aerobic Capacity and Body Composition in Obese Boys After Reduction," Journal of Applied Physiology, 20: 934-937, 1965.

40. J.M. Strang, "Obesity," Diseases of Metabolism, 5th edition, G.G. Duncan, editor (Philadelphia: W.B. Saunders Company, 1964), p. 731.

41. D.J. Turell, R.C. Austin and J.K. Alexander, "Cardio-respiratory Response of Very Obese Subjects to Treadmill Exercise," Journal of Laboratory and Clinical Medicine, 64: 107-116, 1969.

42. R.I. White and J.K. Alexander, "Body Oxygen Consumption and Pulmonary Ventilation in Obese Subjects," Journal of Applied Physiology, 20: 197-201, 1965.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the effect of a physical activity program (lacrosse) on selected anthropometric, physiological and hematological measurements of obese male adolescents, 14 to 17 years of age. Eleven obese students from the Académie de la Salle, Ottawa were designated as the experimental group, and 10 from the University of Ottawa High School the control group. No random selection was carried out. The experimental group participated in two three-quarter hour lacrosse sessions per week for a period of 5 months. Both groups were tested prior to the program and immediately following it.

The data for measurements in the initial testing session were analyzed by the analysis of variance method to determine if any significant differences existed between the groups. If significant differences did exist, the analysis of covariance was employed to analyze the data for measurements in the final testing session. The analysis of variance was used if the groups did not differ significantly.

The analysis of the results indicated that body weight and percent fat were not significantly changed in the experimental group by the program. Although prior to the program, significant differences in chest depth, thigh girth, calf girth, sitting height and fat-free body weight existed below the experimental and control groups, they were not found following the program. The measurements of height, shoulder width, chest breadth, hip width, knee width, chest normal, chest inflated, chest deflated, biceps girth, the abdominal, ankle and gluteal girths, and arm span were not significantly different in the experimental group following the program. There were no significant changes in skinfold measurements in the experimental group as a result of the program.

The heart rate response to sitting rest and steady-state submaximal exercise and during recovery of a work capacity test indicated that a training effect as a result of the program was elicited in the experimental group at all three workloads (360, 720 and 1080 kpm/min). They accomplished these workloads in the final testing session at very significantly lower heart rates from the initial session. Although significant differences in absolute VO_2 at the first resting measurement, the first workload and for the 5 minute recovery period existed between the experimental and control groups prior to the program, they were not found following it. Essentially, the experimental group showed no improvement in absolute VO_2 at rest, and during steady-state submaximal exercise and recovery as a result of the program. With respect to VO_2 ml/kg/min, the experimental group, after 5 months, required significantly less VO_2 ml/kg/min at the first two workloads (360 and 720 kpm/min); this training effect was not found, however, at rest, at the highest workload (1080 kpm/min) and during a 5 minute recovery period.

There were no significant differences in RQ between the experimental and control groups at rest and during the first two workloads (360 and 720 kpm/min) and recovery of the work capacity test. At the highest workload (1080 kpm/min), the RQ of the experimental group was significantly lower than the control group's following the 5 month program. The oxygen pulse of the experimental group at the first resting measurement in the initial testing session differed significantly from that of the control group; in the final session, no significant difference was found. Although no significant difference existed between the two groups at the second resting measurement in the initial session, the oxygen pulse of the experimental group differed significantly from the control group's following the program. There were no significant changes in oxygen pulse in the experimental group during steady-state submaximal exercise at the three workloads and during recovery as a result of the program.

Blood analysis prior to and following the program indicated that hematocrit, hemoglobin, cholesterol and thyroxine levels were not significantly changed in the experimental group as a result of the program.

The data for the variables studied were presented in tabular form and some of these were graphically illustrated.

Conclusions

Within the scope of this study, the following may be concluded:

1. A 5 month program of lacrosse consisting of two three-quarter hour sessions per week for obese male adolescents 14 to 17 years of age was not adequate to elicit a significant change in the anthropometric measurements of body weight, percent fat, fat-free body weight, chest breadth, hip width, knee width, chest depth, chest normal, chest inflated, abdominal girth, gluteal girth, thigh girth, calf girth, ankle girth and the skinfold measurements - cheeks, midaxilla, chest, abdomen, hips, subscapular, triceps, gluteals, front thigh, rear thigh, and biceps. It did, however, increase shoulder width and biceps girth; height and arm span differences remained insignificant between the experimental and control groups. Evidence was presented which indicated that a lack of dietary control, the intensity and length of the program and thereby the energy cost of the program, and differences in rate of training, motivation, degree of movement and actual attendance by the subjects were important factors

influencing the results of the anthropometric and skinfold measurements in the experimental group as a result of the program.

2. A 5 month lacrosse program consisting of two three-quarter hour session per week for obese male adolescents 14 to 17 years of age brought variable significant improvement in the cardio-respiratory variables of a work capacity test. Heart rate was significantly lowered during steady-state submaximal exercise at all three workloads (360, 720 and 1080 kpm/min) reflecting greater efficiency of the cardiovascular system at these workloads. Although no improvement in absolute VO_2 was found, VO_2 ml/kg/min at the workloads of 360 and 720 kpm/min of the work capacity test was significantly lower, reflecting improved mechanical efficiency at these workloads. Evidence was presented that indicated that absolute VO_2 and VO_2 ml/kg/min under similar resting and exercise conditions is greater in obese than non-obese subjects. A lack of similar adolescent studies made comparison of this study's values of absolute VO_2 and VO_2 ml/kg/min impossible. The RQ at the highest workload (1080 kpm/min) was significantly lowered as a result of the program in comparison to a control group, reflecting primarily fat utilization in the experimental group at this workload and carbohydrate utilization by the control group. A second resting oxygen pulse measurement was significantly lower after the 5 month program. Similarly, evidence was presented that indicated oxygen pulse under

similar resting and exercise conditions is greater in obese than non-obese subjects, but comparison of the data of this study with similar adolescent studies was not possible.

3. A 5 month program of lacrosse consisting of two three-quarter hour sessions per week for obese male adolescents 14 to 17 years of age did not significantly change the levels of hematocrit, hemoglobin, cholesterol and thyroxine in the blood. The values of cholesterol prior to and following the program in both the experimental and control groups were above the normal range of values, as is sometimes found for obese subjects. The values of hematocrit and hemoglobin were within the normal range. Similarly, the within-range values of thyroxine supported the evidence of normal thyroxine metabolism in obese adolescents.

Recommendations

The lacrosse program was chosen as the experimental treatment of this study primarily because it would allow for good social interaction (an interest of another party in the investigation) and employ all major muscle groups. It cannot be considered as a high energy cost program because of its content, and number of sessions held per week. For these reasons, an effect upon the variables studied was not to be expected especially when diet was not restricted. It is recommended that in any further study of a similar nature that:

1. A group of normal subjects be utilized for com-

parison of data and furthermore, to provide more insight on physiological and hematological differences between the obese and non-obese at rest, during exercise, in a trained state etc.

2. Dietary restriction or control be carried out.

3. A large sample be obtained utilizing random selection. In addition, based on this study, it would seem that more studies are necessary to investigate what type, intensity, duration and frequency of exercise are necessary to achieve various purposes, for example reduction of obese state, fitness, change in body weight and composition when dietary control or restriction is/is not maintained.

BIBLIOGRAPHY

1. Books

Abstracts of Research Papers. Aapher 1967 Convention.

Andersen, K.L., R.J. Shephard, H. Denolin, E. Varnauskas and R. Masironi. Fundamentals of Exercise Testing. Geneva: World Health Organization, 1971.

Astrand, P.-O. Experimental Studies of Physical Working Capacity in Relation to Sex and Age. Copenhagen: Munksgaard, 1952.

Astrand, P.-O. and K. Rodahl. Textbook of Work Physiology. New York: McGraw-Hill Book Company, 1970.

Blix, G. (ed.). Nutrition and Physical Activity. Sweden: Almquist & Wiksells, 1967.

Brozek, J. (ed.). Human Body Composition. London: Permagon Press, 1965.

Cureton, T.K. Physical Fitness Workbook. Champaign: Stipes Publishing Company, 1944.

Cureton, T.K., et al. Endurance of Young Men. Washington: Society for Research in Child Development, 1945.

Cureton, T.K. Physical Fitness Appraisal and Guidance. St. Louis: The C.V. Mosby Company, 1947.

Cureton, T.K. Physical Fitness of Champion Athletes. Urbana: University of Illinois Press, 1951.

Cureton, T.K. The Physiological Effects of Exercise Programs on Adults. Springfield: C.C. Thomas, 1969.

Davidson, S. and R. Passmore. Human Nutrition and Dietetics. 3rd edition. Edinburgh: E & S. Livingstone, Ltd., 1966.

Dunean, G.G. Diseases of Metabolism, 5th edition. Philadelphia: W.B. Saunders Company, 1964.

Durnin, J.V.G.A. and R. Passmore. Energy, Work and Leisure. London: Heinemann Educational Books, 1967.

Edwards, A.L. Experimental Design in Psychological Research, 3rd edition. New York: Holt, Rinehart and Winston, Inc., 1968.

Exercise Tests in Relation to Cardiovascular Function. Report of a WHO Meeting, Number 388. Geneva: World Health Organization, 1968.

Evang, K. and K.L. Andersen (eds.). International Symposium on Physical Activity in Health and Disease. Baltimore: Williams & Wilkins Co., 1966.

Exercise and Fitness. Chicago: The Athletic Institute, 1959.

Exercise and Fitness. Chicago: The Athletic Institute, 1969.

Faulkner, W.R. and J.W. King (eds.). Manual of Clinical Laboratory Procedure. Cleveland: The Chemical Rubber Company, 1970.

Guyton, A.C. Textbook of Medical Physiology, 3rd edition, Philadelphia: W.B. Saunders Company, 1966.

Harper, H.A. Review of Physiological Chemistry, 12th edition. California: Lange Medical Publications, 1969.

Karpovich, P.V. and W.E. Sinning. Physiology of Muscular Activity, 7th edition. Philadelphia: W.B. Saunders Company, 1971.

Keys, A. (ed.). Weight Control. Iowa: Iowa State College Press, 1955.

Keys, A.,J. Brozek, A. Henschel, O. Michelson and H.L. Taylor. The Biology of Human Starvation. Minneapolis: University of Minnesota Press, 1950.

Kritchevsky, D. Cholesterol. New York: John Wiley & Sons, Inc., 1958.

Kupperman, H.S. Human Endocrinology. Philadelphia: F.A. Davis Company, 1963.

Mayer, J. Overweight, Causes, Cost and Control. Englewood-Cliffs, New Jersey. Prentice-Hall, Inc., 1968.

Morehouse, L.E. and A.T. Miller. Physiology of Exercise, 5th edition. St. Louis: The C.V. Mosby Company, 1967.

Poortmans, J.R. (ed.). Biochemistry of Exercise, Medicine and Sport 3,Baltimore: University Park Press, 1969.

Reader's Digest, January 1971.

Rony, M.R. Obesity and Leaness. Philadelphia: Lea and Febiger, 1940.

Rosenbaum, F.F. and E.L. Belknap (eds.). Work and the Heart. New York: Paul B. Hoeber, Inc., 1959.

Simonson, E. (ed.). Physiology of Work Capacity and Fatigue. Springfield: C. C. Thomas, 1971.

Soupac Manual, University of Illinois, 1969.

The Physical Work Capacity of Canadian Children, The Canadian Association for Health, Physical Education and Recreation, 1968.

The Physical Fitness Performance and Work Capacity of Canadian Adults Aged 18 to 44 Years, The Canadian Association for Health, Physical Education and Recreation, 1971.

Thompson, R.H.S. and E.J. King (eds.). Biochemical Disorders in Human Disease, 2nd edition. London: J. & A. Churchill Ltd., 1964.

Ubbelohde, A.R. Man and Energy. Great Britain: Pelican Books Ltd., 1963.

Wilson, N.L. Obesity. Philadelphia: F.A. Davis Company, 1969.

2. Periodicals

Adams, F.H., E. Bengtsson, H. Berven and C. Wegelius. "The Physical Working Capacity of Normal School Children. II. Swedish City and Country," Pediatrics, 28: 243-257, 1961.

Adams, F.M., L.M. Linde and M. Miyaka. "The Physical Working Capacity of Normal School Children in California, Pediatrics, 28: 55-64, 1961.

Ahlborg, B., G. Ahlborg, M. Aurell and K. Linroth. "Capacity Brief Exercise in Relation to Capacity for Prolonged Exercise in Man," Acta Medicina Scandinavica, Forsvarsmedicin, 3, Supplement 1: 151, 1967.

Alexander, J.K. "Obesity and Cardiac Performance," American Journal of Cardiology, 14: 860-865, 1964.

Andersen, K.L. "Measurements of Work Capacity," Journal of Sports Medicine and Physical Fitness, 4: 236-240, 1964.

Andres, R., G. Cader and K.L. Zierler. "The Quantitatively Minor Role of Carbohydrate in Oxidative Metabolism by Skeletal Muscle in Intact Man in the Basal State. Measurements of O_2 and Glucose Uptake and CO_2 and Lactate Production in the Forearm," Journal of Clinical Investigation, 35: 671-682, 1956.

Astrand, I. "Aerobic Work Capacity in Men and Women with Special Reference to Age," <u>Acta Physiologica Scandinavica</u>, 49: 1, 1960.

Astrand, I., P.-O. Astrand and A. Stunkard. "Oxygen Intake of Obese Individuals during Work on a Bicycle Ergometer," <u>Acta Physiologica Scandinavica</u>, 50: 294-299, 1960.

Astrand, P.-O. "Direct and Indirect Determination of the Maximal Oxygen Uptake," <u>Acta Medica Scandinavica, Försvarsmedicin</u>, 3: 145-150, 1967.

Astrand, P.-A. "Human Physical Fitness with Special Reference to Sex and Age," <u>Physiological Reviews</u>, 36: 307-335, 1956.

Astrand, P.-O. and I. Rhyming. "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate during Submaximal Work," <u>Journal of Applied Physiology</u>, 7: 218-221, 1954.

Astrand, P.-O., I. Astrand, E. Christensen and R. Hedman. "Circulatory and Respiratory Adaptation to Severe Muscular Work," <u>Acta Physiologica Scandinavica</u>, 50: 254-258, 1960.

Balke, B. and R.W. Ware. "The Present Status of Physical Fitness in the Air Force," <u>USAF School of Aviation Medicine</u>, 59-67: 1-9, 1959.

Beaudoin, R. and J. Mayer. "Food Intake of Obese and Non-Obese Women," <u>Journal of the American Dietetic Association</u>, 29: 29-33, 1953.

Behnke, A.R., B.G. Feen and W.C. Welham. "The Specific Gravity of Health Men," <u>Journal of the American Medical Association</u>, 118: 495-497, 1942.

Bengtsson, E. "The Working Capacity in Normal Children Evaluated by Submaximal Exercise on the Bicycle Ergometer and Compared with Adults," <u>Acta Medica Scandinavica</u>, 54: 91-109, 1956.

Bloom, W.L. and M.F. Eidex. "The Comparison of Energy Expenditure in the Obese and Lean," <u>Metabolism</u>, 16: 685-692, 1967.

Bogoroch, R. and P. Timiras. "The Response of the Thyroid Gland of the Rat to Severe Stress," <u>Endocrinology</u>, 49: 548-556, 1951.

Bondy, P.K. and M.A. Hagewood. "Effect of Stress and Cortisone on Plasma PBI and Thyroxine Metabolism in Rats," Proceedings of the Society for Experimental Biology and Medicine, 81: 328-331, 1952.

Bronstein, I.P., S. Wexler, A.W. Brown and A.J. Halpern. "Obesity in Childhood. Psychologic Studies," American Journal of Disabled Children, 63: 238-251, 1942.

Brown, C.E., T.C. Huang, E.L. Bortz and C.M. McCoy. "Observations on Blood Vessels and Exercise," Journal of Gerontology, 11: 292-297, 1956.

Brozek, J. "Changes of Body Composition in Man during Maturity and their Nutritional Implications," Federation Proceedings, 11: 784-793, 1952.

Bruch, M. "Physiological and Psychological Aspects of Food Intake of Obese Children," American Journal of Disabled Children, 59: 739-781, 1940.

Bryans, A.M. "Childhood Obesity - Prelude to Adult Obesity," Canadian Journal of Public.Health, 58: 486-490, 1967.

Bullen, B.A., L.F. Monells, H. Cohen and J. Mayer. "Attitudes Toward Physical Activity, Food and Family in Obese and Nonobese Adolescent Girls," American Journal of Clinical Nutrition, 12: 1-11, 1963.

Bullen, B.A., R.B. Reed and J. Mayer. "Physical Activity of Obese and Nonobese Adolescent Girls Appraised by Motion Picture Sampling," American Journal of Clinical Nutrition, 14: 211-223, 1964.

Buskirk, E.R. "Problems Related to the Caloric Cost of Living," Bulletin of the New York Academy of Medicine, 36: 365-388, 1960.

Buskirk, E. and H.L. Taylor. "Maximal Oxygen Intake and its Relation to Body Composition with Special Reference to Chronic Physical Activity and Obesity," Journal of Applied Physiology, 11: 72-78, 1957.

Campbell, D.E. "Influence of Several Physical Activities on Serum Cholesterol Concentrations in Young Men," Journal of Lipid Research, 6: 478-480, 1965.

Canning, H. and J. Mayer. "Obesity: Analysis of Attitudes and Knowledge of Weight Control in Girls," Research Quarterly, 39: 894-899, 1968.

Carlson, L.A. "Lipid Metabolism and Muscular Work," Federation Proceedings, 26: 1755-1759, 1967.

Chirico, A. and A.J. Stunkard. "Physical Activity and Human Obesity," New England Medical Journal, 263: 935-940, 1960.

Christakis, G., S. Sajecki, R.W. Hillman, E. Miller, S. Blumenthal and M. Archer. "Effect of a Combined Nutrition Education and Physical Fitness Program on the Weight Status of Obese High School Boys," Federation Proceedings, 25: 15-19, 1966.

Conn, J.W. "Obesity. II. Etiological Aspects," Physiological Reviews, 24: 31-45, 1944.

Corbin, C.B. and P. Pletcher. "Diet and Physical Activity Patterns of Obese and Nonobese Elementary School Children," Research Quarterly, 39: 422-429, 1968.

Crews, E.I., K.W. Fuge, L.B. Oscai, J.O. Holloszy and R.E. Shank. "Weight, Food Intake and Body Composition: Effects of Exercise and of Protein Deficiency," American Journal of Physiology, 216: 351-363, 1969.

Cumming, G.R. and P.M. Cumming. "Working Capacity of Normal Children Tested on a Bicycle Ergometer," Canadian Medical Association Journal, 88: 351-355, 1963.

Cumming, G.R. and R. Danzinger. "Bicycle Ergometer Studies in Children," Pediatrics, 32: 202-208, 1963.

Cumming, G.R. and L. Young. "Physical Fitness of Nurses," The Canadian Nurse, 61: 289-291, 1965.

Cureton, T.K. "Physical Fitness Improvement of a Middle-Aged Man, with Brief Reviews of Related Studies," Research Quarterly, 23: 149-160, 1952.

Cureton, T.K. and E.E. Phillips. "Physical Fitness Changes in Middle-Aged Men Attributable to Equal Eight-Week Periods of Training, Non-Training and Retraining," Journal of Sports Medicine and Physical Fitness, 4: 87-93, 1964.

Darling, R.C. "The Significance of Physical Fitness," Archives of Physical Medicine, 28: 140-145, 1947.

Dempsey, J.A. "Anthropometric Observations on Obese and Non-obese Young Men Undergoing a Program of Vigorous Physical Exercise," Research Quarterly, 35: 276-287, 1964.

Dempsey, J.A., W. Reddan, B. Bulke and J. Rankin. "Work Capacity Determinats and Physiologic Cost of Weight - Supported Work in Obesity," Journal of Applied Physiology, 21: 1815-1820, 1966.

De Vries, H.A. and C.E. Klafs. "Prediction of Maximal Oxygen Intake from Submaximal Tests," Journal of Sports Medicine and Physical Fitness, 5: 207-214, 1965.

Dock, W., D. Adlersberg, H.A. Eder, F.E. Kendall and C.F. Wilkinson, Jr. "Curent Concepts in the Management of Arteriosclerosis," Bulletin of the New York Academy of Medicine, 31: 198-219, 1955.

Dorris, R.J. and A.J. Stunkard. "Physical Activity: Performance and Attitudes of a Group of Obese Women," American Journal of the Medical Sciences, 233: 622-628, 1957.

Durnin, J.V.G.A. "The Influence of Nutrition," Canadian Medical Association Journal, 96: 715-718, 1967.

Durnin, J.V.G.A., J.M. Brockway and H.W. Whitcher. "Effects of a Short Period of Training of Varying Severity on Some Measurements of Physical Fitness," Journal of Applied Physiology, 15: 161-165, 1960.

Evans, J.D. and D.E. Parlee. "Polyethanoid Acids as Energy Sources in Resting and Exercised Rats," Federation Proceedings, 16: 35, 1967.

Faris, A.W., F.M. Browning and J.D. Ibach. "The Effect of Physical Training Upon the Total Serum Cholesterol Levels and Arterial Distensibility of Male White Rats," Journal of Sports Medicine and Physical Fitness, 11: 24-27, 1971.

Freedman, M.E., G.L. Snider, P. Brostoff, S. Kimelbrot and L.N. Kalz. "Effects of Training on Response of Cardiac Output to Muscular Exercise in Athletes," Journal of Applied Physiology, 8: 39-47, 1955.

Fry, P.C. "Comparative Study of 'Obese' Children Selected on Basis of Fat Pads," Journal of Clinical Nutrition, 1: 453-467, 1953.

Garn, S.M. and J. Brozek. "Fat Changes During Weight Loss," Science, 124: 682, 1956.

Garrett, L., R.V. Pangle and G.V. Mann. "Effects of Physical Conditioning on Coronary Risk Factors in Men," Federation Proceedings, 24: 262, 1965.

Gertler, M.M., S.M. Garn and H.B. Sprague. "Cholesterol, Cholesterol Esters and Phospholipids in Health and in Coronary Heart Disease. II. Morphology and Serum Lipids in Man," Circulation, 1: 380-391, 1950.

Gofman, J.S., M. Honig, H.B. Jones, M.A. Laufer, E.Y. Lawry, L.A. Lewis, G.V. Mann, F.E. Moore, F. Ohnstead and J.F. Yeager. "Evaluation of Serum Lipoprotein and Cholesterol Complications of Atherosclerosis," Circulation, 14: 691-741, 1956.

Golding, L.A. "Effects of Physical Training upon Total Serum Cholesterol Levels," Research Quarterly, 32: 499-506, 1961.

Hampton, M.C., L.S. Shapiro and R.L. Huenemann. "Helping Teen-age Girls Improve Their Diet," Journal of Home Economics, 53: 835-838, 1961.

Heald, F.P. "Basal Oxygen Consumption in the Obese Adolescent," Journal of Pediatrics, 61: 327-330, 1962.

Hettinger, T., N.C. Birkhead, J.M. Horwath, B. Issekutz and K. Rodahl. "Assessment of Physical Work Capacity," Journal of Applied Physiology, 16: 153-156, 1961.

Hinton, M.A., E.S. Eppwright and H. Chadderdon. "Eating Behavious and Dietary Intake of Girls 12 to 14 Years Old," Journal of the American Dietetic Association, 43: 223-227, 1967.

Holloszy, J.O., J.S. Skinner, G. Toro and T.K. Cureton. "Effects of a Six-Month Program of Endurance Exercise on the Serum Lipids of Middle-Aged Men," American Journal of Cardiology, 14: 733-760, 1964.

Holmgren, A., F. Mossfeldt, T. Sjöstrund and G. Ström. "Effect of Training on Work Capacity, Total Hemoglobin, Blood Volume, Heart Volume and Pulse Rate in Recumbent and Upright Postures," Acta Physiologica Scandinavica, 50: 72-83, 1960.

Huenemann, R.L., M.C. Hampton, L.C. Shapiro and A.R. Behnke. "Adolescent Food Practices Associated with Obesity," Federation Proceedings, 25: 4-10, 1966.

Hung, W., G.P. Gancayeo and F.P. Heald. "Thyroxine Metabolism in Obese Adolescent Males," Pediatrics, 36: 877-881, 1965.

Irvine, C.H.G. "Thyroxine Secretion Rate in the Horse in Various Physiological States," Journal of Endocrinology, 39: 313-320, 1967.

Irvine, C.H.G. "Effect of Exercise on Thyroxine Degradation in Athletes and Non-Athletes," Journal of Clinical Endocrinology and Metabolism, 28: 942-948, 1968.

Issekutz, B., Jr., M.I. Miller, P. Paul and K. Rodahl. "Source of Fat Oxidation in Exercising Dogs," American Journal of Physiology, 207: 583, 1964.

Johnston, L.C. and L.M. Bernstein. "Body Composition and Oxygen Consumption of Overweight, Normal and Underweight Women," Journal of Laboratory and Clinical Medicine, 45: 109-118, 1945.

Johnson, H.L., B.S. Burke and J. Mayer. "The Prevalence and Incidence of Obesity in a Cross-Section of Elementary and Secondary School Children," American Journal of Clinical Nutrition, 4: 231-238, 1956.

Johnson, H.L., B.S. Burke and J. Mayer. "Relative Importance of Inactivity and Overeating in the Energy Balance of Obese High School Girls," American Journal of Clinical Nutrition, 4: 37-44, 1956.

Johnson, T.F., H.Y.C. Wong, R.Y. Shim, K.H.L. Beatrice and A.S. Hall. "The Influence of Exercise on Serum Cholesterol, Phospholipids and Electrophoretic Serum Protein Patterns in College Swimmers," Federation Proceedings, 18: 77, 1959.

Jokl, E. "Effect of Training Upon Obese and Lean Boys," South African Medical Journal, 1945.

Jones, E.M., H.J. Montoye, P.B. Johnson, Sister M.J.M.M. Martin, W.D. Van Huss and D. Cederquist. "Effect of Exercise and Food Restriction on Serum Cholesterol and Liver Lipids," American Journal of Physiology, 207: 460-466, 1964.

Keys, A. and J. Brozek. "Overweight Versus Obesity and the Evaluation of Caloric Needs," Metabolism, 6: 425-434, 1957.

Keys, A., J.T. Anderson, A.M.G. Biorck, J.F. Brodk, B. Bronte-Stewart, F. Fidanze, M.H. Keys, H. Malmros, A. Poppi, T. Posteli, B. Swahn and A. del Vecchio. "Physical Activity and the Diet in Populations Differing in Serum Cholesterol," Journal of Clinical Investigation, 35: 1173-1181, 1956.

Kireilis, R.W. and T.K. Cureton. "The Relationship of External Fat to Physical Education Activities and Fitness Tests," Research Quarterly, 18: 123-134, 1947.

Knehr, C.A., D.B. Dill and W. Neufeld. "Training and its Effect on Man at Rest and at Work," American Journal of Physiology, 136: 148-156, 1942.

Knuttgen, H.G. "Aerobic Capacity of Adolescents," Journal of Applied Physiology, 22: 655-658, 1967.

Kobernick, S.D., G. Nurayama and A.C. Zuchlewski. "Effect of Physical Activity on Cholesterol Atherosclerosis in Rabbits," Proceedings of the Society for Experimental Biology and Medicine, 96: 623-628, 1957.

Larsen, G. "Treatment of Obesity," Tijdsche. f. d. morske, 69: 442-446, 1949.

Larsson, S. "Factors of Importance for the Etiology of Obesity," Acta Physiologica Scandinavica, Supplement 294, 1967.

Lashof, J.C., P.K. Bondy, K. Sterling and E.B. Man. "Effect of Muscular Exercise on Circulating Thyroid Hormone," Proceedings for the Society of Experimental Biology (New York), 86: 233-234, 1954.

Lewis, L.A., F. Olmstead, I.H. Page, E.Y. Lawry, G.V. Mann, F.J. Stare, M. Hanig, M.A. Lauffer and F.E. Moore. "Serum Lipid Levels in Normal Persons. Findings of a Cooperative Study of Lipoproteins and Athosclerosis," Circulation, 26: 227-245, 1957.

Linroth, K. "Testing Physical Working Capacity in Military Personnel," Acta Medica Scandinavica, Försvarsmedicin, 3: 167-171, 1967.

Livas, E.S. "Cholesterolaemia and Arteriosclerosis," Klin. Med. Mosk., 38: 137, 1957.

MacBryde, C.M. "The Diagnosis of Obesity," The Medical Clinics of North America, 48: 1307-1316, 1964.

Mahadeva, K., 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.

Malhotra, M.S., S.S. Ramaswamy and S.N. Roy. "Influence of Body Weight on Energy Expenditure," Journal of Applied Physiology, 17: 433-435, 1962.

Malina, R.M. "Exercise as an Influence Upon Growth," Clinical Paediatrics, 8: 16-26, 1969.

Mann, G.V., K. Teel, O. Hayes and A. McNally. "Exercise in the Disposition of Dietary Calories," New England Journal of Medicine, 253: 349-355, 1955.

Mayer, J. "Genetic, Traumatic and Environmental Factors in the Etiology of Obesity," Physiological Reviews, 33: 422-508, 1953.

Mayer, J. "Obesity: Etiology and Pathogenesis," Postgraduate Medicine, 25: 623-634, 1959.

Mayer, J. "The Obese Hyperglycemic Syndrome of Mice as an Example of'Metabolic'Obesity," American Journal of Clinical Nutrition, 8: 740-745, 1960.

Mayer, J. "Genetic Factors in Obesity," Bulletin of the New York Academy of Medicine, 36: 323-343, 1960.

Mayer, J. "Obesity: Physiologic Considerations," American Journal of Clinical Nutrition, 9: 530-537, 1961.

Mayer, J. "Physical Activity and Anthropometric Measurements of Obese Adolescents," Federation Proceedings, 25: 11-14 1966.

Mayer, J., N.B. Marshall, J.J. Vitale, J.H. Christensen, M.B. Mashayekhi and F.J. Stare. "Exercise, Food Intake and Body Weight in Normal Rats and Genetically Obese Adult Mice," American Journal of Physiology, 177: 544-548, 1954.

Mayer, J., P. Roy and K.P. Mitra. "Relation between Caloric Intake, Body Weight and Physical Work in an Industrial Male Population in West Bengal," American Journal of Clinical Nutrition, 4: 169-175, 1956.

Mayer, J., C. Zomzely and F.J. Stare. Experimentia, 13: 250, 1957.

McArdle, W.D. and J.R. Magel. "Physical Work Capacity and Maximum Oxygen Uptake in Treadmill and Bicycle Exercise," Medicine and Science in Sports, 2: 118-123, 1970.

McAtte, B.J. and S. Grollman. "The Effects of Exercise and Training on the Hematology of the Female Albino Rat," Journal of Sports Medicine and Physical Fitness, 7: 205-213, 1967.

McCance, R.A. "Overnutrition and Undernutrition. I. Causes," Lancet, 2: 685-690, 1953.

McNelly, W.C. "Some Effects of Training on the Respiratory Response to Exercise," American Journal of Physiology, 116: 100-101, 1936.

Métivier, G. "Changes in the Total Blood Serum Cholesterol Level, Cardiovascular Condition and Adiposity of Adult Males Following One Season of Ice Hockey," Medical Services Journal of Canada, 22: 411-422, 1966.

Miller, A.T. and C.S. Blythe. "Influence of Body Type and Body Fat Content on the Metabolic Cost of Work," Journal of Applied Physiology, 8: 139-141, 1955.

Miller, D.S. and P. Mumford. "Obesity: Physical Activity and Nutrition," Proceedings of the Nutrition Society, 24-25: 100-107, 1965-66.

Mitchell, J.M. and G. Blomquist. "Maximal Oxygen Uptake," New England Journal of Medicine, 284: 1018-1022, 1971.

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

Montoye, H.J., W.D. Van Huss, W.D. Braver, E.M. Jones, M.A. Ohlson, E. Mahoney and H. Olson. "The Effects of Exercise on Blood Cholesterol in Middle-Aged Men," American Journal of Clinical Nutrition, 7: 139-145, 1959.

Moody, D.L., J. Kollias and E.R. Buskirk. "Evaluation of Aerobic Capacity in Lean and Obese Women with Four Test Procedures," Journal of Sports Medicine and Physical Fitness 9: 1-9, 1969.

Moore, F.E. "Serum Cholesterol Levels of Adults," (United States 1960-62), National Centre for Health Statistics, 11: 1-23, 1967.

Moore, M.E., A. Stunkard and L. Srole. "Obesity, Social Class and Mental Illness," Journal of the American Medical Association, 181: 962-966, 1962.

Myasnikov, A.L. "Influence of Some Factors on Development of Experimental Cholesterol Atherosclerosis," Circulation, 17: 99-113, 1958.

Naughton, J. and B. Balke. "Physical Working Capacity in Medical Personnel and the Response of Serum Cholesterol to Acute Exercise and to Training," American Journal of the Medical Sciences, 247: 286-292, 1964.

Naughton, J. and J.F. McCoy. "Observations on the Relationship of Physical Activity to the Serum Cholesterol Concentration of Healthy Men and Cardiac Patients," Journal of Chronic Diseases, 19: 727-733, 1966.

Naughton, J. and F. Nagle. "Peak Oxygen Intake during Physical Fitness Program for Middle-Aged Men: Measurement of Changes by Laboratory and Field Testing," Journal of the American Medical Association, 191: 899-901, 1965.

Newburg, L.H. and M.W. Johnston. "The Nature of Obesity," American Journal of Physiology, 197-213, 1929.

Newman, F., B.F. Smalley and M.L. Thomson. "Effect of Exercise, Body and Lung Size on CO Diffusion in Athletes and Non-Athletes," Journal of Applied Physiology, 17: 649-655, 1962.

Oscai, L.B. and B.T. Williams. "Effects of Exercise on Overweight Middle-Aged Males," Journal of the American Geriatrics Society, 16: 794-797, 1968.

Parizkova, J. and L. Stankova. "Influence of Physical Activity on a Treadmill on the Metabolism of Adipose Tissue in Rats," British Journal of Nutrition, 18: 325-332, 1964.

Pascale, L., M.I. Grossman, M.S. Sloane and J. Frankel. "Correlations between Thickness of Skinfolds and Body Density in 88 Soldiers," Human Biology, 28: 165-176, 1956.

Passen, S. and R. von Saleski. "A Semiautomated Method Which Does Not Require Digestion for the Determination of Serum Thyroxine Iodine (T4)," American Journal of Clinical Pathology, 15: 166-176, 1969.

Passmore, R. "A Note on the Relation of Appetite to Exercise," Lancet, 4: 29, 1958.

Passmore, R. and J.V.G.A. Durnin. "Human Energy Expenditure," Physiological Reviews, 35: 801-840, 1955.

Peckos, P., J. Spargo and F. Heald. "Program and Results of a Camp for Obese Adolescent Girls," Postgraduate Medicine, 27: 527-533, 1960.

Pitts, G.C. "Body Fat Accumulation in the Guinea Pig," American Journal of Physiology, 185: 41-48, 1956.

Pollack, H., C.F. Consolazio and G.J. Isaac. "Metabolic Demands as a Factor in Weight Control," Journal of the American Medical Association, 167: 216-219, 1958.

Pollack, M.L., T.K. Cureton and M.S. Greninger. "Effects of Frequency of Training on Work Capacity, Cardiovascular Function and Body Composition of Adult Men," Medicine and Science in Sports, 1: 70-74, 1969.

Reichlin, S., M.G. Koussa and F.W. Witt. "Effect of Prolonged Sleep Therapy and of Chlorpromazine on Plasma Protein-Bound Iodine Concentration and Plasma Thyroxine Turnover," Journal of Clinical Endocrinology, 19: 692-699, 1959.

Rhodes, B.A. "Effect of Exercise on the Thyroid Gland," Nature, 216: 917-918, 1967.

Roberts, J.C. and R.H. Wilkins. "Atherosclerosis in Obese Patients at Autopsy," Circulation, 18: 495, 1958.

Robinson, S. "Metabolic Adaptations to Exhausting Work as Affected by Training," American Journal of Physiology, 133: 428, 1941.

Robinson, S. and P.M. Harmon. "Effects of Training and of Gelatin Upon Certain Factors which Limit Muscular Work," American Journal of Physiology, 133: 161-169, 1941.

Robinson, S., H.T. Edward and D.B. Dill. "New Records in Human Power," Science, 85: 409-410, 1937.

Roby, F.B. "Effect of Exercise on Regional Fat Accumulation," Research Quarterly, 33: 273-277, 1962.

Rochelle, R.H. "Blood Plasma Cholesterol Changes during a Physical Training Program," Journal of Sports Medicine and Physical Fitness, 1:63-70, 1961.

Rodahl, K., P.-O. Astrand, N.C. Birkhead, T. Hettinger, B. Issekutz, D.M. Jones and R. Weaver. "Physical Work Capacity," Archives of Environmental Health, 2: 499-510, 1961.

Rowell, R.B., H.L. Taylor and Y. Wang. "Limitations to Prediction of Maximal Oxygen Intake," Journal of Applied Physiology, 19: 919-927, 1964.

Schade, M., F.A. Hellebrandt, J.C. Waterland and M.L. Carns. "Spot Reducing in Overweight College Women: Its Influence on Fat Distribution as Determined by Photography," Research Quarterly, 33: 461-540, 1962.

Schneider, E.C. and C.B. Crampton. "A Comparison of Some Respiratory and Circulatory Reactions of Athletes and Non-Athletes," American Journal of Physiology, 129: 165-170, 1940.

Seliger, V. and V. Zelenka. "Physical Fitness of Czech Children at 12 and 15 Years of Age," Acta Universitatis Carolinae Gynica, 5, 1970.

Seltzer, C.C. and J. Mayer. "Serum Iron and Iron-Binding Capacity in Adolescents. II. Comparison of Obese and Non-Obese Subjects," American Journal of Clinical Nutrition, 13: 354-361, 1963.

Sjostrand, T. "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," Acta Medica Scandinavica, 196: 687-699, 1947.

Sjostrand, T. "The Significance of the Pulmonary Blood Volume in the Regulation of the Blood Circulation under Normal and Pathological Conditions," Acta Medica Scandinavica, 145: 155-168, 1953.

Sjostrand, T. "Testing of the Physical Working Capacity. Definition, History and Application," Acta Medica Scandinavica, Försvarsmedicin, 3: 141-144, 1967.

Skinner, J.S., J.O. Holloszy and T.K. Cureton. "Effects of a Program of Endurance Exercises on Physical Work," American Journal of Cardiology, 14: 747-752, 1964.

Skold, N. "Training of Conscripts and Ordinary Military Personnel," Acta Medica Scandinavica, Försvarsmedicin, 3: 175-182, 1967.

Sprynarova, S. and J. Parizkova. "Changes in the Aerobic Capacity and Body Composition in Obese Boys after Reduction," Journal of Applied Physiology, 20: 934-937, 1965.

Stefanik, P.A., B. Bullen, F.P. Heald and J. Mayer. "Physical Performance, Skinfold Measurements, Activity Expenditures and Food Consumption of College Women," Research Quarterly, 32: 229-237, 1961.

Stefanik, P.A., F.P. Heald and J. Mayer. "Caloric Intake in Relation to Energy Output of Obese and Nonobese Adolescent Boys," American Journal of Clinical Nutrition, 7: 55-61, 1959.

Strom, G. "Recommended Symbols, Nomenclature and Criteria for Certain Measures of Physical Capability," Acta Medica Scandinavica, Försvarsmedicin, 3: 159-160, 1967.

Stunkard, A. "Physical Activity, Emotions and Human Obesity," American Practitioners and Digest of Treatment, 10: 1500-1, 1959.

Stunkard, A. and J. Pestka. "The Physical Activity of Obese Girls," American Journal of Clinical Nutrition, 103: 812-817, 1963.

Tanner, J.M. "The Relation between Serum Cholesterol and Physique in Healthy Young Men," Journal of Physiology, 115: 371-390, 1951.

Taylor, C. "Studies in Exercise Physiology," American Journal of Physiology, 135: 27-42, 1941-42.

Taylor, H.L., J.A. Anderson and A. Keys. "Effect on Serum Lipids of 1300 Calories of Daily Walking," Federation Proceedings, 16: 128, 1957.

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

Thomas, B.M. and A.T. Miller. "Adaptation to Forced Exercise in the Rat," American Journal of Physiology, 193: 350-354, 1958.

Thompson, C.W. "Changes in Body Fat Estimated from Skinfold Measures of Varsity College Football Players during a Season," Research Quarterly, 30: 87-93, 1959.

Thompson, C.W., E.R. Buskirk and R.F. Goldman. "Changes in Body Fat Estimated from Skinfold Measures of College Basketball and Hockey Players during a Season," Research Quarterly, 27: 418-430, 1956.

Turell, D.J., R.C. Austin and J.K. Alexander. "Cardiorespiratory Response of Very Obese Subjects to Treadmill Exercise," Journal of Laboratory and Clinical Medicine, 64: 107-116, 1969.

Volpé, R., J. Vale and W.J. MacAllister. "The Effects of Certain Physical and Emotional Tensions and Strains on Fluctuations in the Level of Serum Protein-Bound Iodine," Journal of Clinical Endocrinology, 20: 415-428, 1960.

Von Döbeln, W. "Human Standard and Maximal Metabolic Rate in Relation to Fat-Free Body Mass," Acta Physiologica Scandinavica, 37, Supplement 126, 1956.

Wahlund, H.G. "Determination of the Physical Working Capacity: A Physiological and Clinical Study with Special Reference to Standardization of Cardio-Pulmonary Functional Tests," Acta Medica Scandinavica 132, Supplement 215: 9-86, 1948.

Warnock, N.H., T.B. Clarkson and R. Stenvenson. "Effect of Exercise on Blood Coagulation Time and Atherosclerosis of Cholesterol-Fed Cockerels," Circulation Research, 5: 478-480, 1957.

Watson, D. Clin. Chim. Acta, 5: 637, 1960.

Welch, B.E., 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, 1958.

Wells, J.B., J. Parizkova and E. Jokl. "The Kentucky Physical Fitness Experiment," Journal of the Association for Physical and Mental Rehabilitation, 15-17: 69-72, 1961-63.

Wells, J.B., J. Parizkova, J. Bohanan and E. Jokl. "Growth, Body Composition and Physical Efficiency," Journal of the Association for Physical and Mental Rehabilitation, 15-17: 39-40, 1961-63.

Wenzell, B.J., H. Stults and J. Mayer. "Hypoferremia in Obese Adolescents," Lancet, 2: 327, 1962.

White, R.I. and J.K. Alexander. "Body Oxygen Consumption and Pulmonary Ventilation in Obese Subjects," Journal of Applied Physiology, 20: 197-201, 1965.

Williams, R.H. "Relation of Obesity to the Function of the Thyroid Gland, Especially as Indicated by the Protein-Bound Iodine Concentration in the Plasma," Journal of Clinical Endocrinology and Metabolism, 8: 257-261, 1948.

Wilkinson, C.F., E.A. Hand and N.T. Flieglman. "Essential Familial Hypercholesterolemia," Annals of Internal Medicine, 29: 671, 1948.

Wilson, O. "Field Study of the Effect of Cold Exposure and Increased Muscular Activity Upon Metabolic Rate and Thyroid Function in Man," Federation Proceedings, 25; 1357-1362, 1966.

Wong, H.Y.C., M.B. Anderson, J.K. Lin, D.J. Liu and E.W. Hawthorne. "Hypocholesterolizing Effect of Exercise on Cholesterol-Fed Cockerels," Proceedings of the Federation of American Societies for Experimental Biology, 16: 138, 1957.

Wurm, M., R. Kositchek and R. Straus. "Lipoprotein Quantitated by Paper Electrophoresis as an Index of Atherosclerosis," Circulation, 21: 526-537, 1960.

Young, C.M. "The Prevention of Obesity," The Medical Clinics of North America, 48: 1317-1333, 1964.

Zöllner, N. Dtsch. med. Wschr., 84: 389, 1959.

3. Unpublished Materials

Andersen, K.L. and M. Kai, Chairmen, Committee on Physiological Measurements and Indices.

Baycroft, G.H. "An Evaluation of the Modified Astrand-Rhyming Nomogram as an Estimator of Maximal Oxygen Consumption," Unpublished M.Sc. thesis, University of Alberta, 1964.

Cooper, L.A. "A Comparison of the Effects of Short Intensive and Prolonged Exercise Programs on Treadmill Performance and Certain Cardio-Respiratory Functions." Unpublished M.Sc. thesis, University of Alberta, 1963.

Coyne, L.L. "The Relationship of Maximal Oxygen Intake to Body Composition and Total Body Weight in Active Males." Unpublished M.Sc. thesis, University of Alberta, 1963.

Dempsey, J. "The Effects of Caloric Restriction and Muscular Activity on Body Composition." Unpublished Paper, University of Alberta, 1962.

Fox, E.L., C.E. Billings, R. Bason and D.K. Mathews." Improvement of Physical Fitness by Interval Training." Unpublished Research, 1967.

Hinton, M. "Factors Related to the Eating Behaviour and Dietary Adequacy of Girls 12 to 14 Years of Age." Unpublished Ph.D. dissertation, Iowa State University and Technology, 1962.

Jetté, M.J. "A Study of Long-Term Physical Activity in Sedentary Middle-Aged Men." Unpublished Ph.D. dissertation, University of Illinois, 1969.

Jetté, M.J. and J.S. Thoden, "A Profile of the Canadian Cross-Country Ski-Team". Unpublished Research, 1970.

Mohr, D.R. "Changes in Waistline and Abdominal Girth and Subcutaneous Fat Following Isometric Exercises." Unpublished Research, 1964.

Schlegel, R.P. "Obesity as a Factor in Health, Disease and Longevity." Unpublished Research Paper, University of Illinois, 1966.

Walker, R.A. "Changes in Body Fat as Computed from Skinfold Measures of College Track and Field Athletes during a Season of Competition and Training." Unpublished M.Sc. thesis, South Dakota State College, 1959.

Yuhasz, M.S. "The Effects of Sports Training on Body Fat in Man: with Predictions of Optimal Body Weight," Unpublished Ph.D. dissertation, University of Illinois, 1962.

APPENDIX A

LETTER TO PARENTS

UNIVERSITÉ D'OTTAWA
OTTAWA 2 CANADA
UNIVERSITY OF OTTAWA
ÉCOLE D'ÉDUCATION PHYSIQUE ET DE RÉCRÉATION
DÉPARTEMENT DE KINANTHROPOLOGIE
SCHOOL OF PHYSICAL EDUCATION AND RECREATION
DEPARTMENT OF KINANTHROPOLOGY

Le 17 novembre 1970

Chers Parents,

Votre fils, nous a exprimé le désir de participer à un programme d'exercices et de sports. Ce programme aura lieu après les heures de classe, soit de 3:20 à 4:10 p.m. au gymnase de l'Académie et durera pour les prochains six mois. Nous croyons fermement qu'un tel programme lui sera des plus avantageux, particulièrement en ce qui a trait à sa santé physique.

Afin d'évaluer l'influence du programme sur nous vous serions des plus reconnaissants si vous lui permettiez de prendre un examen médical ainsi que certains tests de laboratoire à l'Université d'Ottawa. Votre approbation peut être exprimée en signant au bas de la lettre dans l'espace réservée à cette fin, laquelle vous voudrez bien nous retourner dans l'enveloppe ci-jointe.

De plus, nous voulons vous assurer qu'il n'y a aucun coût pour ce programme. Si vous désirez de plus amples renseignements, vous n'avez qu'à me téléphoner soit à l'Université (231-4077) ou à la maison (824-4874).

Veuillez recevoir l'expression de mes sentiments les plus distingués.

Bien à vous,

Maurice Jetté, Ph.D.
Professeur adjoint

/ld
Pièce jointe

J'accepte que mon fils participe au programme de sports et d'exercices et qu'il subisse un examen médical et les tests nécessaires en vue d'évaluer l'influence de ce programme sur sa santé.

Signature ______________________

No. OHSIP: ....

No. Assurance Hôpital ....

APPENDIX B

WORK CAPACITY TEST EQUIPMENT PHOTOGRAPHS

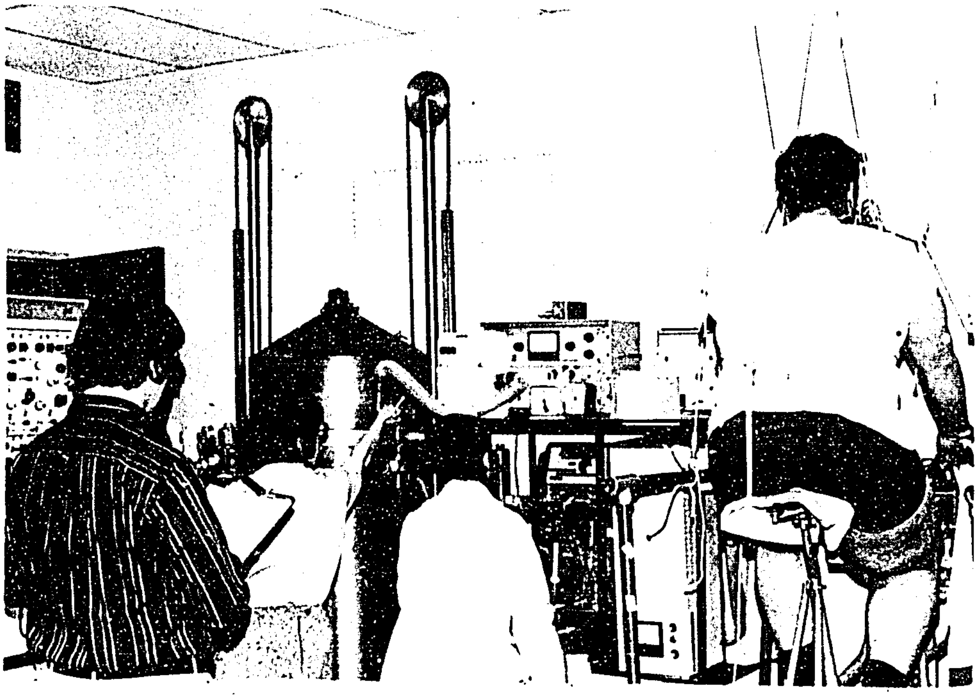

Plate 1. View of Open Circuit System

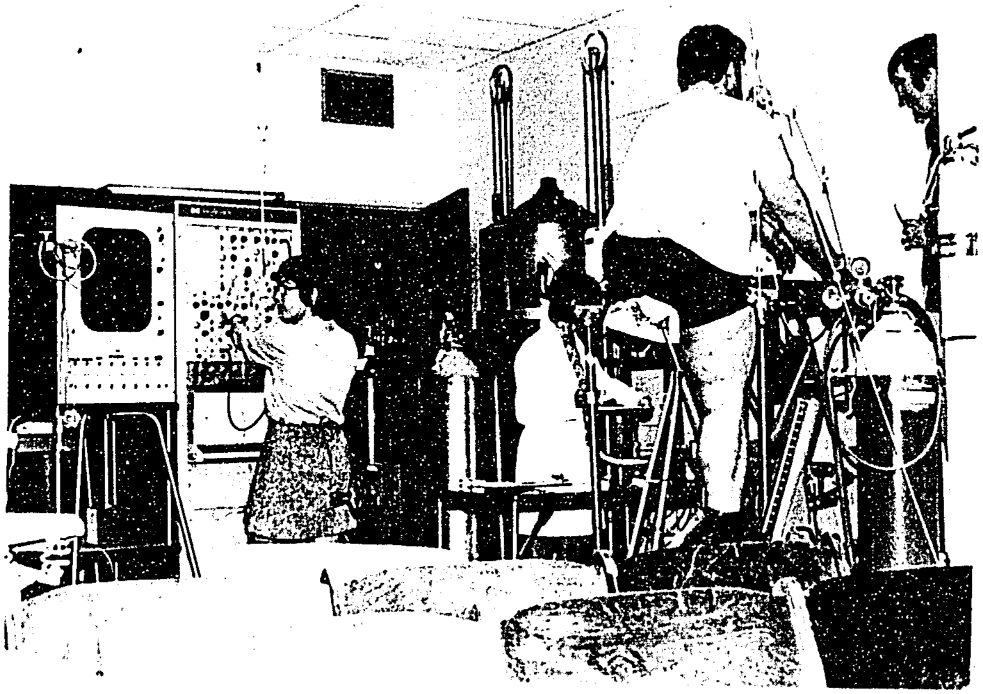

Plate 2. View of Sanborn, Polygraph And Electrocardiotachograph

APPENDIX C

PHOTOGRAPHS OF SUBJECTS WITH HIGHEST AND LOWEST PERCENT BODY FAT

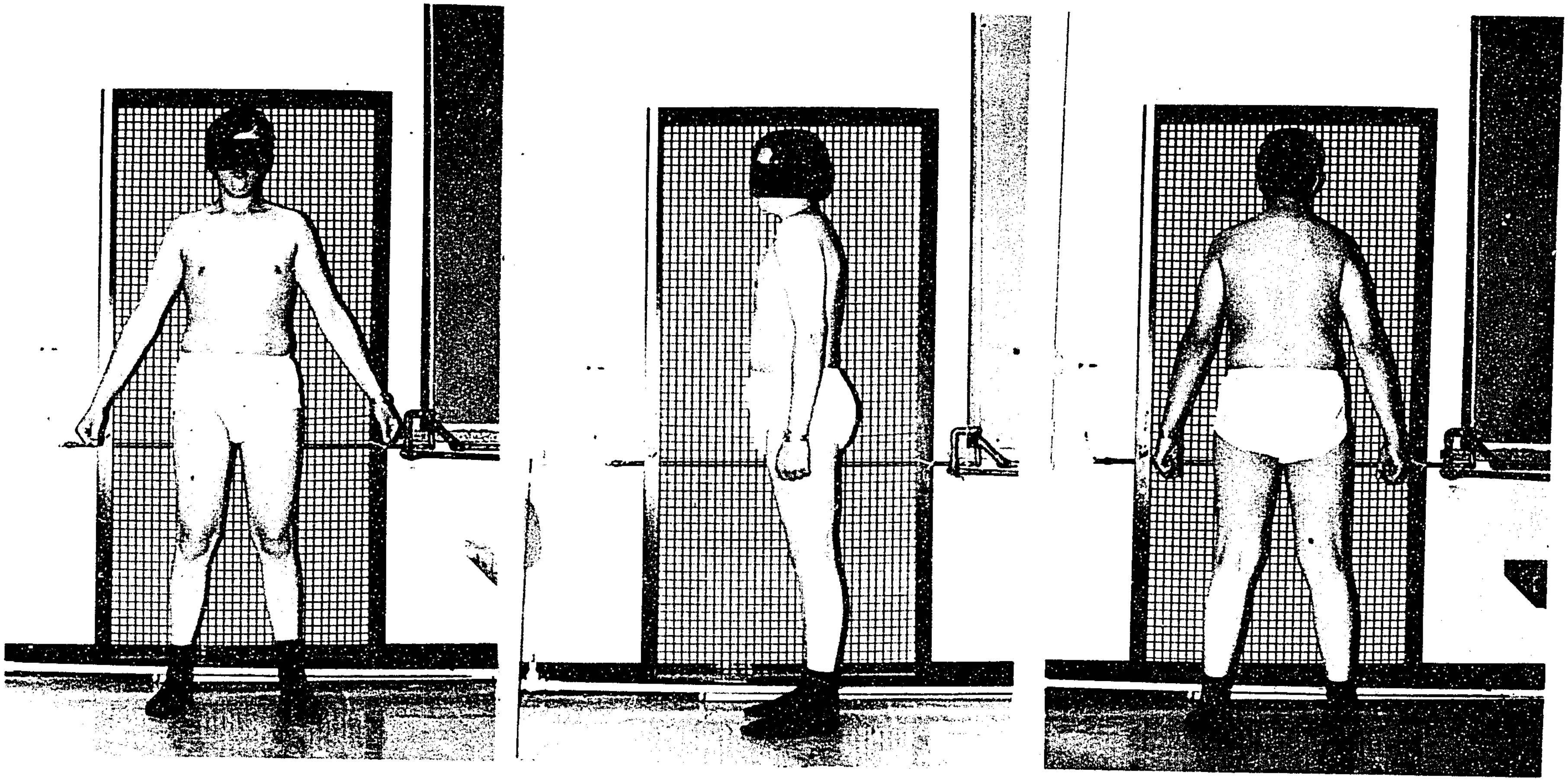

Plate 1. Lowest Percent Body Fat for Obese Subjects of Study

Initial Session - Subject S.F. - 23% Body fat

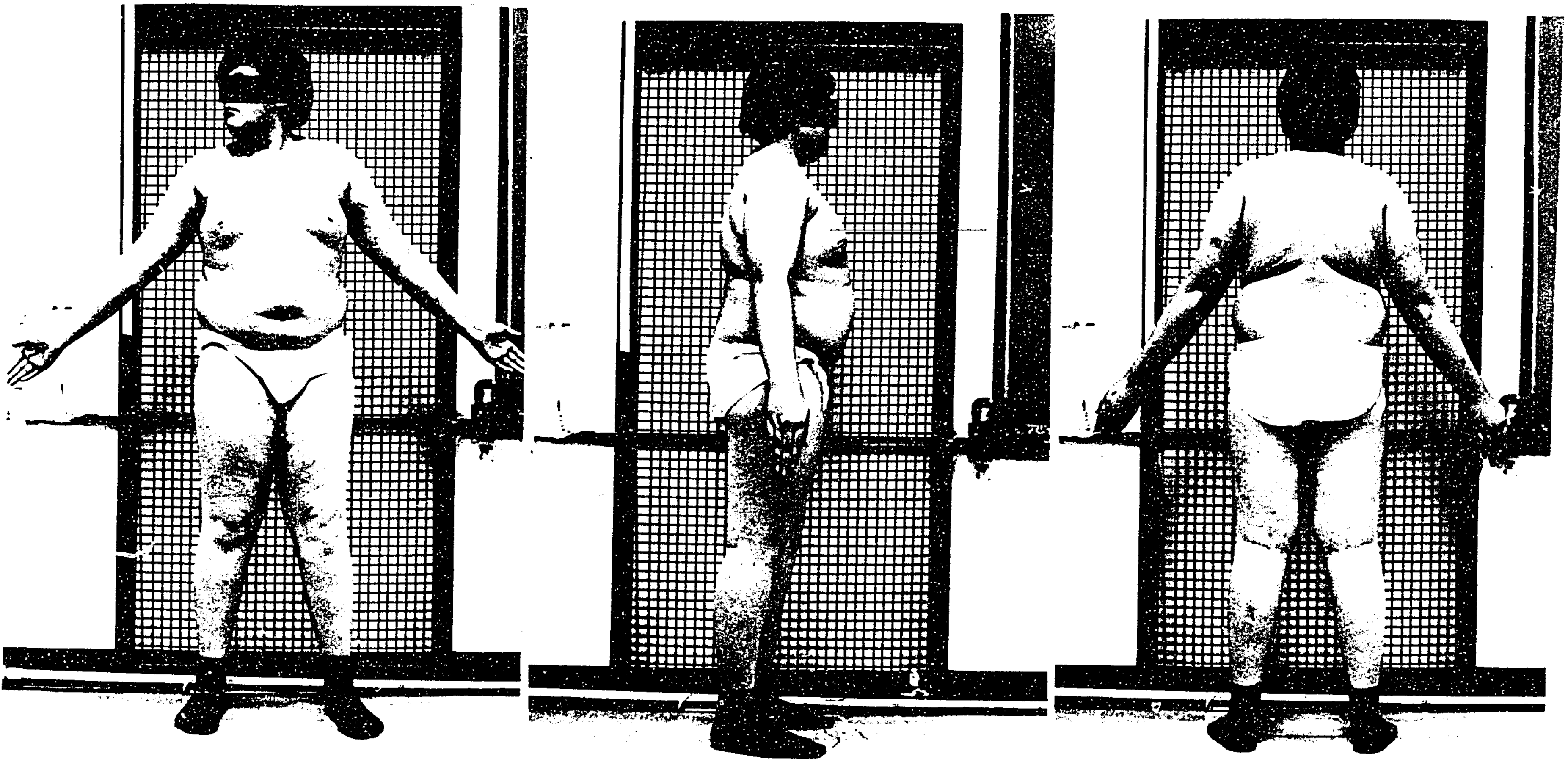

Plate 3. Highest Percent Body Fat for Obese Subjects of Study

Final Session - Subject M.D. - 39% Body fat

APPENDIX D

SUMMARY OF STATISTICAL ANALYSIS

SUMMARY OF STATISTICAL ANALYSIS

Analysis of Variance

Variable	df	MSb	MSw	F	
Anthropometric Measurements					
(Initial Data)					
Height	1,19	18.657	6.223	2.29	
Weight	1,19	5369.906	1235.012	4.34	
Fat	1,19	1.773	24.949	0.07	
Fat-Free Body Weight	1,19	2729.272	373.650	7.30	(.05)
Shoulder Width	1,19	.960	1.637	0.58	
Chest Breadth	1,19	2.553	1.183	2.15	
Hip Width	1,19	.785	1.612	0.48	
Knee Width	1,19	.494	.870	0.56	
Chest Depth	1,19	5.925	1.230	4.81	(.05)
Biceps Girth	1,19	3.194	1.583	2.01	
Chest Normal	1,19	21.162	19.651	1.07	
Chest Inflated	1,19	33.890	15.949	2.12	
Chest Deflated	1,19	38.288	19.043	2.01	
Abdominal Girth	1,19	45.164	24.461	1.84	
Gluteal Girth	1,19	48.524	16.734	2.89	
Thigh Girth	1,19	33.649	4.795	7.01	(.05)
Calf Girth	1,19	11.943	1.743	6.84	(.05)
Ankle Girth	1,18	1.057	.256	4.12	(.05)
Arm Span	1,19	16.225	16.934	0.95	
Sitting Height	1,19	23.724	3.168	7.48	(.05)
Anthropometric Measurements					
(Final Data)					
Height	1,19	18.050	5.055	3.57	
Weight	1,19	5081.158	1246.480	4.07	
Fat	1,19	16.125	21.201	0.76	
Fat-Free Body Weight	1,19	1758.545	393.007	4.47	(.05)
Shoulder Width	1,19	17.892	1.843	9.70	(.01)
Chest Breadth	1,19	3.923	1.526	2.57	
Hip Width	1,19	4.601	2.185	2.10	
Knee Width	1,19	.288	.342	0.84	
Chest Depth	1,19	2.262	.580	3.90	
Biceps Girth	1,19	9.610	1.811	5.30	(.05)
Chest Normal	1,19	46.573	17.762	2.62	
Chest Inflated	1,19	31.886	15.850	2.01	
Chest Deflated	1,19	37.520	19.948	1.88	
Abdominal Girth	1,19	56.072	21.058	2.60	
Gluteal Girth	1,19	28.459	18.050	1.57	
Thigh Girth	1,19	7.680	5.740	1.33	

SUMMARY OF STATISTICAL ANALYSIS (continued)

Variable	df	MSb	MSw	F	
Calf Girth	1,19	7.842	1.548	5.06	(.05)
Ankle Girth	1,19	1.043	.289	3.60	
Arm Span	1,19	13.716	12.962	1.05	
Sitting Height	1,19	27.950	2.050	13.62	(.01)
Skinfold Measurements					
(Initial Data)					
Cheeks	1,19	.731	16.522	0.04	
Midaxilla	1,19	25.604	53.726	0.47	
Chest	1,19	21.431	32.231	0.66	
Abdomen	1,18	91.138	45.668	1.99	
Hips	1,19	116.067	42.945	2.70	
Subscapular	1,19	28.548	65.350	0.43	
Triceps	1,19	12.896	50.264	0.25	
Gluteals	1,17	12.636	25.936	0.48	
Front Thigh	1,18	33.281	44.452	0.74	
Rear Thigh	1,10	1.322	31.450	0.04	
Biceps	1,15	751.373	1671.854	0.44	
Skinfold Measurements					
(Final Data)					
Cheeks	1,19	28.837	10.436	2.76	
Midaxilla	1,19	2.560	38.835	0.06	
Chest	1,19	187.886	44.427	4.22	
Abdomen	1,19	168.777	43.421	3.88	
Hips	1,18	139.392	40.558	3.43	
Subscapular	1,19	154.910	86.281	1.79	
Triceps	1,19	.001	37.067	0.00	
Gluteals	1,16	11.377	38.136	0.29	
Front Thigh	1,18	.466	70.646	0.00	
Rear Thigh	1,2	18.253	35.293	0.51	
Biceps	1,17	14.480	26.113	0.55	
Hematological Measurements					
(Initial Data)					
Hemoglobin	1,19	3.098	1.177	2.63	
Hematocrit	1,19	15.875	8.075	1.96	
Cholesterol	1,19	1642.729	474.237	3.46	
Thyroxine	1,19	1.522	2.144	0.70	
Hematological Measurements					
(Final Data)					
Hemoglobin	1,19	.936	1.255	0.74	

SUMMARY OF STATISTICAL ANALYSIS (continued)

Variable	df	MSb	MSw	F
Hematocrit	1,19	17.751	8.159	2.17
Cholesterol	1,19	921.506	553.233	1.66
Thyroxine	1,19	.009	.923	0.01
Cardio-Respiratory Measurements				
(Initial Data)				
Resting Heart Rate, Rest 1	1,19	131.906	139.222	0.94
Resting Heart Rate, Rest 2	1,18	39.200	114.044	0.34
Exercise Heart Rate, 1 kp	1,19	225.664	184.112	1.22
Exercise Heart Rate, 2 kp	1,18	11.250	198.250	0.05
Exercise Heart Rate, 3 kp	1,18	84.050	296.383	0.28
Resting Oxygen Consumed, Rest 1	1,19	.230	.025	8.88 (.05)
Resting Oxygen Consumed, Rest 2	1,17	.150	.041	3.65
Exercise Oxygen Consumed, 1 kp	1,18	.159	.034	4.55 (.05)
Exercise Oxygen Consumed, 2 kp	1,16	.055	.104	0.53
Exercise Oxygen Consumed, 3 kp	1,18	.287	.071	4.01
Recovery Oxygen Consumed	1,13	.066	.011	4.80 (.05)
Resting Respiratory Quotient, Rest 1	1,19	.096	.022	4.19
Resting Respiratory Quotient, Rest 2	1,17	.024	.019	1.24
Exercise Repiratory Quotient, 1 kp	1,18	.009	.028	0.33
Exercise Respiratory Quotient, 2 kp	1,16	.015	.009	1.70
Exercise Respiratory Quotient, 3 kp	1,18	.013	.006	2.14
Recovery Respiratory Quotient	1,13	.037	.014	2.63
Resting Oxygen Consumption, Rest 1	1,19	8.265	2.206	3.74
Resting Oxygen Consumption, Rest 2	1,17	8.519	5.160	1.65

SUMMARY OF STATISTICAL ANALYSIS (continued)

Variable	df	MSb	MSw	F	
Exercise Oxygen Consumption, 1 kp	1,18	.089	.039	0.02	
Exercise Oxygen Consumption, 2 kp	1,16	4.083	9.034	0.45	
Exercise Oxygen Consumption, 3 kp	1,18	3.216	19.424	0.16	
Recovery Oxygen Consumption	1,13	.018	.908	0.02	
Resting Oxygen Pulse, Rest 1	1,19	20.007	3.093	6.46	(.05)
Resting Oxygen Pulse, Rest 2	1,16	17.204	6.553	2.62	
Exercise Oxygen Pulse, 1 kp	1,18	5.051	2.759	1.83	
Exercise Oxygen Pulse, 2 kp	1,16	1.722	4.571	0.37	
Exercise Oxygen Pulse, 3 kp	1,18	18.470	4.742	3.89	
<u>Cardio-Respiratory Measurements</u>					
(Final Data)					
Resting Heart Rate, Rest 1	1,18	4.274	118.918	0.03	
Resting Heart Rate, Rest 2	1,19	42.682	109.954	0.38	
Exercise Heart Rate, 1 kp	1,19	266.084	91.820	2.89	
Exercise Heart Rate, 2 kp	1,19	1077.958	101.280	10.64	(.01)
Exercise Heart Rate, 3 kp	1,18	812.032	96.264	8.43	
Resting Oxygen Consumed, Rest 1	1,18	.002	.005	0.46	
Resting Oxygen Consumed, Rest 2	1,19	.018	.005	3.19	
Exercise Oxygen Consumed, 1 kp	1,19	.039	.031	1.25	
Exercise Oxygen Consumed, 2 kp	1,19	.058	.035	1.64	
Exercise Oxygen Consumed, 3 kp	1,18	.006	.099	0.06	
Recovery Oxygen Consumed	1,18	.019	.009	2.01	
Resting Respiratory Quotient, Rest 1	1,18	.020	.014	1.38	

SUMMARY OF STATISTICAL ANALYSIS (continued)

Variable	df	MSb	MSw	F
Resting Respiratory Quotient, Rest 2	1,19	.010	.011	0.86
Exercise Respiratory Quotient, 1 kp	1,19	.007	.013	0.57
Exercise Respiratory Quotient, 2 kp	1,19	.039	.011	3.53
Exercise Respiratory Quotient, 3 kp	1,18	.086	.017	4.85 (.05)
Recovery Respiratory Quotient	1,19	.021	.014	1.49
Resting Oxygen Consumption, Rest 1	1,18	2.507	1.052	2.38
Resting Oxygen Consumption, Rest 2	1,19	.174	1.484	0.11
Exercise Oxygen Consumption, 1 kp	1,19	64.099	11.011	5.82 (.05)
Exercise Oxygen Consumption, 2 kp	1,19	88.028	14.037	6.27 (.05)
Exercise Oxygen Consumption, 3 kp	1,18	60.466	16.093	3.75
Recovery Oxygen Consumption	1,19	.983	.705	1.39
Resting Oxygen Pulse, Rest 1	1,18	.028	.622	0.04
Resting Oxygen Pulse, Rest 2	1,19	3.174	.514	6.16 (.05)
Exercise Oxygen Pulse, 1 kp	1,19	.475	2.613	0.18
Exercise Oxygen Pulse, 2 kp	1,19	.162	2.978	0.05
Exercise Oxygen Pulse, 3 kp	1,18	7.525	4.923	1.52

APPENDIX E

RAW DATA

The Raw Data May be Obtained from the
Department of Kinanthropology, University of Ottawa.