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The effects of aerobic training on basal metabolic rate

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THE EFFECTS OF AEROBIC TRAINING ON BASAL METABOLIC RATE

by

Victoria Kingston Tatro

An Abstract

of a thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the School

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Thesis Advisor: Dr. G. A. Sforzo

ABSTRACT

The purpose of this study was to investigate the effects of aerobic exercise training on the basal metabolic rate (BMR) of untrained individuals. Females between 20 and 30 years of age from the Ithaca College community were the subjects for this study. Two groups of subjects, an experimental group (_n_ = 6), and a control group (_n_ = 5), participated in two BMR measurements, skinfold measurements, and a pretraining graded exercise test (GXT). An 8-week exercise training program was prescribed for each experimental subject, and each subject participated in a posttraining GXT, two BMRs, and skinfold measurements. The analysis on responses to the GXT found there was a significant increase in peak VO_2 for the exercise group, which indicated a significant training effect from the exercise program, while the control group showed no significant change in peak VO_2. The analysis on body fat percentages revealed no significant difference between the two groups. Also, neither group showed a significant change in body fat percentage over the training period. An ANOVA block design revealed no significant (p > .05) change in BMR over time or between groups. Although it may be possible that aerobic training may cause a change in BMR, it was concluded that at a training level of peak VO_2 of 35.32 ml/kg/min, aerobic training does not have a chronic effect on BMR.

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Victoria Kingston Tatro

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

Thesis Advisor:

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Chairman, Graduate Programs in Physical Education:

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Date: 5/2/88

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the School of Health, Physical

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DEDICATION

To Penny and Amy, my little girls, for their love, understanding and patience, more than any mother could expect.

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Chapter 1

INTRODUCTION

Of all deaths in the United States, 48% are attributed to negative factors in our lives that are alterable (e.g., lifestyles) (Center for Disease Control, 1981, pp. 10-17). In recent years there has been a growing interest in improving wellness habits to prevent some of these deaths (i.e., preventive medicine compared to just treating the illness once it occurs). Some aspects of preventive medicine are exercise, diet with weight control, and reducing daily stress. Aerobic exercise increases cardiopulmonary fitness and may reduce the risk of coronary heart disease. Diet and weight control are important aids in combatting high blood pressure, diabetes, back pain, and some forms of cancer, and in reducing the risk of coronary heart disease. Reducing stress also helps in maintaining good mental health and reducing risks of high blood pressure. Therefore, it is clear that regular exercise, weight control, and stress reduction are critical to the health of the human organism, and it is conceivable that these components interact with each other to have a further impact upon health. One such interrelationship may be that habitual exercise influences weight control by altering basal metabolic rate (BMR) (i.e., the amount of energy required to sustain the body's vital functions in the waking state).

Knowledge of any effect of exercise upon basal metabolism over an extended period of time may be helpful to individuals trying to maintain or obtain their desired body weight. Numerous studies have been conducted to determine if exercise training has an effect on basal metabolism (Bender, 1951; deVries & Gray, 1963; Finch, 1978; Leilich, 1948; Morehouse, 1937; Nielsen, 1950; Van Huss, 1949), but these have had conflicting results. The purpose of the present study was to examine the effects of cycle ergometer training on BMR by controlling some of the variables not controlled in past studies.

Scope of the Problem

Proper weight control is vital to wellness, therefore, knowledge of the relationship of regular aerobic exercise to the BMR of an individual over an extended period of time could help establish the daily caloric intake best suited for that individual. This investigation was conducted to examine the role of regular aerobic exercise on BMR by looking at the effects of 8 weeks of aerobic training on a Monark cycle ergometer on the BMR of 6 untrained females ages 20-30 years; 5 additional female subjects acted as controls. Each subject had two oxygen consumption (VO_2) tests to determine the subject's BMR prior to a graded exercise test (GXT). The GXT was used to prescribe the exercise level for the experimental group at a given percentage of their peak VO_2 over the 8-week training period and establish a baseline peak VO_2 for both the experimental and control group values. After the 8 weeks of training, both groups of subjects participated in a second GXT to determine if there had been a significant increase in their peak VO_2 over the course of the 8 weeks, which would indicate a training effect. At least 3 days after any exercise, two separate VO_2 tests for BMR were again conducted on each subject.

Statement of the Problem

Effects of 8 weeks of aerobic training on a Monark cycle ergometer on the BMR of women 20 to 30 years of age were investigated.

Null Hypothesis

Training 8 weeks on a Monark cycle ergometer has no effect on BMR as measured by indirect calorimetry of women between the ages of 20 and 30 years.

Assumptions

This investigation was conducted with the following assumptions:

1. The subjects did not change their lifestyle, diet, and exercise routine, other than the prescibed exercise protocol for the experimental group, from the time this study began until all testing had been completed.

2. The subjects for this investigation followed the pretest instructions for the four BMR readings and the two GXTs.

Definition of Terms

In this investigation, these terms were defined as follows:

Postprandial: no food ingested for the previous 12 hr.

Untrained: a person who has not engaged in regular aerobic exercise within the 3 months prior to the testing.

Delimitations

The design of this study contained the following delimitations:

1. The experimental subjects were 6 untrained females between the ages of 20 and 30 years from the Ithaca College community.

2. All testing took place in the Exercise Physiology Laboratory at Ithaca College using a cycle ergometer.

3. All testing took place in a climate controlled environment of ($M \pm SD$) 22.2 $^{\circ}$ $\pm$ 1.0 $^{\circ}$C temperature, 735 mm $\pm$ 5.9 mm Hg barometric pressure, and 47.2% $\pm$ 4.3% relative humidity.

4. BMR was measured utilizing open circuit indirect calorimetery.

5. Aerobic training of the experimental group was executed on Monark cycle ergometers for 8 weeks.

6. Graded exercise testing was done on the Jaeger Ergotest cycle ergometer.

7. This study was conducted during the winter and spring months.

Limitations

The design of this study contained the above delimitations that limit the interpretation of the results of this study. These limitations are as follows:

1. The results can only be generalized to young untrained female populations.

2. Testing under other environmental conditions may produce different results.

3. The results of this study may not be applicable when other modes of graded exercise testing are used.

4. The results of this study may not be applicable when other modes of aerobic training are used.

5. Peak VO_2 rather than VO_2 max was determined because the graded exercise test was performed on the cycle ergometer, which may not have yielded results equal to other modalities of testing.

6. No control was exerted over the subjects' diets, which may affect the results of the BMR readings.

7. The results may be affected by the use of volunteer experimental subjects who were interested in aerobic training.

8. The results may be affected by the use of controls with a wide range of training states.

9. Testing during other seasons may produce different results.

Chapter 2

REVIEW OF LITERATURE

The purpose of this investigation was to study the effects of aerobic exercise training on basal metabolic rate (BMR). Awareness of any possible influence of regular exercise on BMR could help one better understand the role of exercise in weight control. This chapter contains a review of the literature related to BMR and exercise. The topics reviewed are (a) factors influencing energy expenditure and (b) effects of exercise on energy expenditure.

Factors Influencing Energy Expenditure

To understand proper weight control it is necessary to examine the energy balance equation of energy intake and energy expenditure (EE). Total daily EE is a result of the following three components: BMR, dietary-induced thermogenesis (DIT), and the energy cost of physical activity. This section will cover the topics of BMR, DIT, and energy cost of activity.

BMR

BMR is the amount of energy required to sustain life, that is, for circulation, tissue repair, respiration, excretion, maintenance of body temperature, and maintenance of muscle tone. BMR is measured in the waking state while mentally, emotionally, and physically at rest, and 12 hr postprandial. BMR is influenced by a number of factors including surface area and body composition, age, sex, temperature, and climate.

Surface area and body composition. Of all the factors affecting BMR, surface area and body composition are the most influential. BMR depends on body size because 70% to 80% of the total basal energy expenditure is in the form of heat, which is dependent on the surface area of the body. Heat production results from oxidative metabolic processes, which are dependent upon the consumption of oxygen.

When BMR is estimated by means of indirect calorimetry, determinations are made by the amount of oxygen consumed by the body. For each liter of oxygen consumed approximately 5 kcal of energy are produced. The standard formula used in past studies (deVries & Gray, 1963; Finch, 1978) to compute BMR (kcal/m^2/hr) considers body surface area (m^2) (Consolazio, Johnson, & Pecora, 1963). BMR is expressed in kcal/m^2/hr because heat production, and in turn, body heat loss are more closely related to body surface area than to body weight (Montoye & Ayen, 1986). Fleish (1960) examined five popular formulas to determine surface area and stated the DuBois-Mech formula ($m^2 = \text{weight}^{0.425} \times \text{height}^{0.725} \times 71.85$) is the most accurate to use when calculating BMR.

Recent researchers (Ravussin, Burnand, Schutz, & Jequier, 1982, 1985; Schutz, Bessard, & Jequier, 1984) have suggested body composition is most important in expressing

BMR because lean body mass is metabolically more active than adipose tissue. Obese subjects are known to display a significantly greater BMR when BMR is expressed in absolute terms (kcal/24 hr). However, BMR in obese, moderately obese, and average weight subjects have shown no significant difference when expressed on the basis of surface area and fat free mass (FFM). Therefore, it was concluded that obese subjects have a greater amount of FFM than subjects of normal weight and a good predictor of BMR could be obtained from the measurement of FFM (Ravussin et al., 1985). When obese subjects were fed a low calorie diet for 10-16 weeks, BMR dropped (M = 9%) in direct proportion to the decrease in FFM. There was a high correlation between the decline in BMR with the decrease in FFM on a hypocaloric diet with restricted exercise (Ravussin et al., 1985). Schutz et al. (1984) reported an increase in BMR in obese subjects that was thought to be due to an increase in FFM of these subjects. When BMR was expressed on the basis of FFM, it was the same for both groups. A significant correlation was observed between BMR and FFM (r = .870, p < .001). Therefore, it seems FFM has a strong influence on BMR. It would follow that maintaining muscle mass while on a calorie-restricted diet would help keep BMR elevated to aid in caloric deficit.

Age and sex. BMR increases from birth to age 5, then it declines with age except for a slight rise during adolescence. The decline in BMR is 1 to 2% per decade throughout an individual's life (Keys, Taylor, & Grande, 1973). Nielsen (1950) suggested this decline is due to the loss of muscle tone because of lessening periods of physical activity. In a cross sectional survey of males 20 to 75 years old, the change in BMR with age was proportional to the amount of body weight made up of fat mass (Keys et al., 1973). Therefore, the reduction of BMR is probably due mainly to differences in body composition that develop with age.

BMR is 5% to 10% lower in females than in males of similar size and age. This difference, also, seems to be related to body composition because females generally have more body fat than men. However, when BMR is expressed in units of FFM, the difference between the sexes is eliminated (McArdle, Katch, & Katch, 1986).

Temperature and climate. Claremont (1972) found BMR increased in a cold environment. These findings are similar to those of McArdle, Magel, Lesmes, and Pechar (1976), who found that oxygen consumption at rest was greater when subjects were immersed in 18 °C water. They explained these findings by suggesting shivering thermogenesis had occurred and stated that there is an increase in oxygen consumption due to energy required to sustain shivering as the body attempted to counter the heat drain to the cold water. Van Huss (1949) also reported a relationship between BMR and temperature. He found air temperature has an inverse relationship with BMR. Since environmental temperatures have an effect on BMR, one might question if there is a seasonal effect of temperature on BMR (i.e., an acclimation of BMR to changing seasons).

Yoshimura, Yukiyoshi, Yoshioka, and Takeda (1966) reported Japanese subjects showed a climatic adaptation of BMR. In the winter BMR increased, and in the summer BMR decreased. This was further verified by seasonal variations in the thyroid activity of the Japanese subjects. However, Canadians living in Japan showed no seasonal change in BMR during the same time period. It was concluded that the factors causing a difference in BMR among the two groups could be physical stature, dietary intake (especially fat intake), and physical work. Both dietary intake and physical work may have enhanced thyroid activity, inhibiting the BMR reduction normally seen in the summer, which could explain why the thyroid activity of the Canadians remained at a constant level. Galvao (1950) studied the BMR of men living in Sao Paulo, Brazil, New York City, and Boston. Those living in Sao Paulo exhibited a lower BMR than those living in the temperate zone. This difference in BMR was considerable for small and middle weight men, but not so great for heavier men. It was concluded that BMR was elevated in colder climates to compensate for an increased rate of heat loss through the skin, due to a greater difference of temperature between the skin surface and the environment. In summary, the wide discrepancy in results makes unclear any consistent effect seasonal change might have upon BMR.

DIT

Specific dynamic action (SDA) is the extra heat produced as the result of food ingestion. Of all foods, proteins are the best stimulators of SDA. However, SDA can not completely explain the increase of postprandial heat production. Therefore, Miller, Mumford, and Stock (1967) suggested the term dietary-induced thermogenesis rather than SDA because factors other than dietary composition can influence the calorigenic effect of a meal and physical training level apparently plays a role in that respect (LeBlanc, Diamond, Cote, & Labrie, 1984). DIT is considered the total EE induced by food intake. This includes the energy cost of digestion, absorption of nutrients, and the energy required for nutrient transformation or storage (Tremblay, Despres, & Bouchard, 1985). When BMR was taken preprandially and 2.5 hr postprandially, researchers found that thermic response to a meal was 7-10% of the ingested calories (Miller et al., 1967). The maximum thermic response generally occurred 1 hr postprandial. Bray, Whipp, and Koyal (1974) had similar findings, reporting that the thermic effect of food on BMR was 10% of the BMR. However, Miller et al. (1967) found the alteration in DIT to result in a 19-34% increase in BMR. Pacy, Barton, Webster, and Garrow (1985) reported DIT elevated BMR 22% over 165 min following a meal. Although, there is agreement that BMR is elevated postprandially, a wide range of values have been reported (10-34% increase in BMR). Miller et al. (1967) observed the thermic response in the resting state varied with the size of the meal. As the caloric value of the meal increased, so did the thermic response. However, Bray et al. (1974) found little effect of the size of the meal on thermic response, but the DIT effect of three meals over a 24-hr period was blunted for obese individuals despite the fact they had a higher energy intake than the controls of average weight. In conclusion, the research varies in the magnitude of DIT, if any, in response to meals of different caloric size. The magnitude of DIT also seems to vary with body composition.

Energy Cost of Activities

Daily activities use calories above the energy required for BMR and DIT. Of the EE components, physical activity could most easily be altered to change the balance of energy intake and energy output. The average individual can increase his/her metabolic rate tenfold through aerobic exercise such as running or swimming. The amount of EE for an activity is dependent on duration and intensity. The magnitude of the energy cost of activity may be also due to efficiency of movement and body mass. Efficiency of physical activity seems to have an effect on the total caloric cost of the activity. Trained and untrained wood cutters were reported to have had an average EE of 300 kcal/hr, but the trained cut four times as much wood as the untrained at nearly the same caloric output (Morehouse & Miller, 1963). Ravussin et al. (1982) found obese subjects expend 8% more energy than nonobese over 24 hr because the energy cost of moving was increased due to moving excess weight. In experimentally produced obesity, increases in percentage of EE on treadmill walking were of the same magnitude as the percentage of weight gain (Hanson, 1973). In summary, as body mass increases so does the EE of activity involving transport of the body, and as the efficiency of movement increases the EE of activity decreases.

Effects of Exercise on Energy Expenditure

If exercise has an effect on EE beyond the energy cost of the activity (i.e., altering BMR or DIT), this influence of exercise would be a facet to consider in a weight control program.

BMR

Several studies have shown exercise elevates BMR for several hours postexercise. Hermansen, Grandmontagne, Moehlum, and Ingnes (1984) reported BMR was elevated 12-24 hr postexercise. DeVries and Gray (1963) found BMR elevated (M = 4.39 kcal/m^2/hr) for 6 hr postexercise, and Finch (1978) found it to be increased for 4 hr postexercise. This increase in BMR may be due to a sustained heat production due to increased catecholamine levels in the blood for many hours after exercise. The magnitude of the increase in oxygen consumption reported by Claremont (1972) was 33% in excess of that required for the recovery of oxygen debt. Although it has been shown that BMR is elevated for a period of time following a single bout of exercise, there is very little information on the effect of exercise training on BMR.

Tremblay, Cote, and LeBlanc (1983) found individuals who engaged in regular and intense training (i.e., 12 to 16 hr/week) exhibited a higher BMR than normal, but moderately trained individuals (i.e., exercising 6 to 10 hr/week) showed essentially the same BMR as sedentary individuals (Tremblay, Fontaine, & Nadeau, 1985). These findings are slightly different than those reported in an earlier study by Leilich (1948), who reported untrained subjects had a lower BMR than subjects at three training levels: physical education majors, varsity athletes, and highly trained athletes. LeBlanc, Mercier, and Samson (1984) observed BMR was slightly higher in competitive athletes than in moderately active and sedentary female subjects. It appears training level may affect BMR, but whether this is due to training or a reduction in body fat that accompanies training is an important question. LeBlanc, Mercier, and Samson (1984), Tremblay et al. (1983), and Tremblay, Fontaine, and Nadeau (1985) reported body fat percentage was lower for the highly trained individual. Tremblay, Fontaine, and Nadeau (1985) reported the trained subects had lower body fat percentages than nontrained subjects. Tremblay et al. (1983) reported a lower body weight and FFM in trained athletes than moderately active individuals ($\underline{M} \pm SE$ = 9.1% ± 1.2% and 10.7% ± 1.8%, respectively). LeBlanc, Mercier, and Samson (1984) found competitive athletes had a significantly lower percentage of body fat than moderately active and sedentary subjects ($\underline{M} \pm SE$ = 17.5% ± 1.0%, 21.2% ± 1.2%, and 22.2% ± 1.4%, respectively). These studies were cross-sectional studies which compared the BMR and body composition of groups of different training levels rather than following the same subjects over a training period. Because there is a high correlation between FFM and BMR, any change in body composition as a result of training should be taken into account when observing BMR in a longitudinal study.

Morehouse (1937) studied athletes in and out of training and found a slight rise in BMR during training, which he concluded was due to increased muscle mass. Nielsen (1950) recorded an increase in BMR in subjects over a fall semester of swimming classes at the beginning and intermediate skill levels. Bender (1951) found BMR was increased by endurance-type exercise (i.e., aerobic exercise). Unfortunately, in these training studies a change in body mass or body composition was not reported. Therefore it is unclear as to whether the change in BMR was due to training or an increase in FFM and decrease in fat.

DIT

There have been numerous studies done on the possibility that exercise may potentiate DIT. Do DIT and the caloric cost of exercise have a synergistic effect? Miller et al. (1967) found a meal stimulates metabolic rate and the heightened metabolic rate is further stimulated by exercise. When VO_2 was measured during a step test, the thermic response to a 1,000-kcal meal was about two times as great compared to the the thermic response of a meal at rest. Similar results were recorded by Bray et al. (1974). They found the thermic effect of breakfast was increased about twofold by exercise when the caloric intake exceeded 1,000 kcal. This response was not significantly altered by dietary modifications (i.e., weight gain, high or low protein diet). However, Segal and Gutin (1983) did not get these same results. The key finding in their study was exercise potentiated the thermic effect of food for lean subjects but not for obese subjects. The large difference in thermogenic response to the combination of food and exercise was found in spite of the fact both groups had very similar responses to the thermogenic effect of food at rest and to preprandial exercise. From these studies it is hard to draw firm conclusions on the role of a single bout of exercise as a potentiator of DIT, and exercise training may have a different effect on DIT than a single bout of exercise.

Tremblay et al. (1983) observed a markedly lower thermic response to a meal in highly trained subjects than in nontrained subjects. LeBlanc, Mercier, and Samson (1984) and LeBlanc, Diamond, Cote, and Labrie (1984) produced these same results; the increased thermic response of a meal above BMR was greater for untrained individuals than trained individuals. Tremblay et al. (1983) concluded this reduced thermic response to a meal seen in trained subjects is an adaptive response to spare carbohydrates for exercise. In well trained subjects prolonged training would bring about asparing effect on glycogen and increase its storage to be readily available for the purpose of performing work. To support this belief, Tremblay, Fontaine, and Nadeau (1985) observed 47% higher glucose-induced thermogenesis in untrained subjects compared to endurance trained subjects. The glucose storing of the endurance trained individuals corresponded with the reduction of glucose-induced thermogenesis. The transformation of glucose into glycogen is more energy efficient than transforming glucose into lipids. Also, in trained subjects, the contribution of glucose into energy is reduced while its transformation into glycogen is enhanced (LeBlanc, Mercier, & Samson, 1984).

Summary

To maintain an energy balance and body weight, the energy intake must equal energy expenditure. To lose weight there must be an increase in energy expenditure above the energy intake. EE is made up of three components: BMR, DIT, and energy cost of physical activities. BMR is the amount of energy required to sustain the body's vital functions resting in the waking state, 12 hr postabsorbtion. BMR is influenced by body surface area and body composition. Surface area is best determined by the DuBois-Mech formula, which is used to determine BMR of an individual. There is a high correlation between BMR and FFM. As FFM increases so does BMR. The decrease in BMR with age appears to be a result of decreased FFM. The lower BMR observed in females seems to be due to a lower FFM than in males of the same age and size. Environmental temperature has an inverse effect on BMR, but it is unclear as to whether there are seasonal variations in BMR. DIT is the energy expenditure induced by food intake, which includes digestion, absorption of nutrients, and the energy for their transformation or storage. Various researchers have recorded thermic response to a meal ranging from 10% to 34% of BMR. The maximum thermic response seems to occur 1 hr postprandial. The energy cost of physical activity seems to be the component of EE most easily altered. Increased physical activity increases daily caloric uptake, whereas, efficiency of movement decreases energy required for the activity.

The question of whether exercise potentiates BMR and DIT still remains to be fully answered. It has been known that after a single bout of exercise BMR is elevated for several hours, but the research on exercise training's influence upon BMR is not conclusive. BMR seems to increase for trained subjects, but is this due to the high level of cardiovascular fitness, change in body composition, or hormonal adaptation? DIT seems to be potentiated by exercise, but trained subjects apparently have a lesser thermic response to a meal than untrained subjects. This may be a result of an adaptation of glucose storage in trained subjects that is more calorie efficient and allows for glucose to be readily available for work.

It is clear to see that the research done on BMR and exercise has resulted in some conflicting results due to difficulties in choosing parameters that are easily measured and give consistent results.

Chapter 3

METHODS

This chapter describes the procedures used to investigate the effects of 8 weeks of aerobic training upon basal metabolic rate (BMR). BMR, skinfold measurements, and functional capacity were examined in two groups of Ithaca College females. The methods of subject selection, BMR testing, BMR calculations, skinfold measurements, graded exercise testing, training protocol, and data analysis will be discussed in the following sections. These procedures were approved by the All College Review Board on Human Subject Research at Ithaca College.

Subject Selection

The subjects for this study were an experimental group of 6 untrained females between the ages of 21 and 26 years and a control group of 5 aerobically trained females between 20 and 30 years of age. All the subjects were volunteers recruited from the Ithaca College community. Recruitment letters were sent out to 498 females on the staff and faculty at Ithaca College (see Appendix A). Potential subjects attended an orientation to familiarize the subjects with the procedures and the equipment to be used in the study and to provide the subjects with instructions for testing and training. Medical and exercise training histories and an informed consent for the study (see

Appendixes B, C, and D) were also completed at this time. Of the 34 individuals who responded to the recruitment letter, 11 females were selected to participate in the research project. Selection was based on age, medical history, and training status. During the time period of this study, the subjects were instructed not to change their daily living habits (see Appendix E). Specific reminders included the following:

1. Subjects were instructed not to make any changes in their exercise routine other than the prescribed exercise for the treatment group.

2. Subjects were instructed not to make any dietary changes during the course of the study.

3. Subjects were required to keep a diary of menstruation during the time frame of the study.

Prior to the training period, all subjects were required to complete two oxygen consumption (VO_2) tests for BMR readings, two sets of skinfold measurements, and a graded exercise test. Identical readings were also made following 8 weeks of aerobic training on Monark cycle ergometers by the exercise group.

<u>BMR Test</u>

Methods widely used for measuring BMR include direct and indirect calorimetry. For this study indirect measurements of basal metabolism were made using open circuit measurement of VO_2 for a minimum of 10 min. Two measurements were performed prior to the exercise training period, and two measurements were taken 9 weeks later, after the posttraining GXT was performed. Each subject was given an information sheet including instructions to be followed the night and the morning before the BMR testing (Appendix E). Verbal explanation of the following points were given to each subject prior to each test day:

1. Subjects were instructed to have a good sleep the night prior to testing.

2. Subjects were instructed not to eat or drink for 12 hr prior to testing. This included not drinking coffee or tea on the morning of the test. Caffeine in large doses can increase cardiac output and alter the metabolism by increasing fatty acid mobilization (Lamb, 1984). Bray et al. (1974) found the thermic effect of food increased resting metabolic rate (RMR) by 10% over the RMR without food, whereas, Miller et al. (1967) found the thermic effect of a meal increased RMR by 25%. The subjects were also instructed to eat a meal low in protein the night before the test because protein may increase BMR due to dietary-induced thermogenesis (Miller et al., 1967).

3. Subjects were instructed not to consume alcohol the night prior to testing.

4. Subjects were instructed not to engage in moderate to intense exercise within 24 hr prior to testing, or engage in unusually intense exercise 3 days prior to the test. DeVries and Gray (1963) found RMR to be elevated 6 hr postexercise, and Finch (1978) found RMR to be elevated 4 hr postexercise. The subjects were instructed to do as little activity as possible between the time they woke up and the time they reported to the laboratory. This included not showering prior to the BMR test.

5. Subjects were instructed to report to the laboratory by the same mode of transportation for each BMR test (Finch, 1978).

All the BMR testing was conducted in the Exercise Physiology Laboratory in the Hill Center at Ithaca College between the hours of 6:00 a.m. and 10:00 a.m. Each BMR trial was performed at the same time of the morning for the individual subject. The BMR readings were conducted in a dimly lit room with the temperature (M ± SD = 22.2 ± 1.0 °C), barometric pressure (735 ± 5.9 mm Hg), and relative humidity (47.2 ± 4.3%) closely controlled. For more valid comparisons of BMR, Van Huss (1949) found temperature conditions should be standardized and maintained at 19.8 °C to 20.9 °C, which is ideal according to the Sanborn Testing Manual (Consolazio et al., 1963). Bender (1951) found 25.3 °C to 26.4 °C ideal, with a light blanket to prevent chilling. Shivering increases oxygen consumption because of increased metabolism needed for additional heat production to maintain a constant body temperature. Therefore, subjects in the present study were provided a blanket if needed.

Upon arrival at the laboratory, subjects were weighed, and height was measured. Immediately following the height and weight measurements, the subjects lay down for a minimum of 30 min. After 30 min of rest, blood pressure (BP), heart rate (HR), and oral body temperature were taken. Subjects were then fitted with a mouthpiece and nose clip. After 5 min of breathing through the mouthpiece, the subjects' BP and HR were taken again. If BP and HR were elevated, subsequent BP and HR readings were taken every 5 min until two consecutive measurements were consistent (Park et al., 1983). With the subjects lying perfectly still, VO_2 readings were recorded for 10 min (McArdle et al., 1986; Nagy & King, 1983) at 30-s intervals using rapid gas analyzers (Applied Electrochemistry S-3A oxygen analyzer and Beckman LB-2 carbon dioxide analyzer) and a Rayfield RAM-9200 gas meter, interfaced with an Apple IIe computer system.

BMR Calculations

The calculations for determining BMR were done using the procedures and formulas as stated by Consolazio et al.

(1963). These formulas have been used by deVries and Gray (1963) and more recently by Finch (1978) in studies of exercise and BMR.

Surface area was calculated for each of the subjects by applying the subject's height and weight to the nomogram constructed from the DuBois-Mech formula (Consolazio et al., 1963). To determine the BMR of each subject before and after training the mean VO_2 (ml O_2/ min) for the two 10-min trials and the subject's surface area were put into the following formula:

$$\underset{(\text{kcal}/\ \text{m}^2/\ \text{hr})}{\text{heat production}} = \frac{(\text{ml } O_2/\ \text{min})(291.72)}{\text{surface area } (\text{m}^2)}.$$

<u>Skinfold Measurements</u>

Skinfold measurements were taken immediately following each of the BMR tests. Using Lange Skinfold Calipers the following three sites were measured on the left side of the subject's body:

1. Thigh: vertical fold midway between the inguinal fold and patella on the anterior midline.

2. Tricep: vertical fold midway between the acromion process and the olecranon process.

3. Suprailiac: oblique fold over the high point of the iliac crest.

All sites were measured three times, and the mean for each site was used to determine body composition by the following formulas from Jackson, Pollock, and Ward (1980):

Body Density = 1.0994921 − [(9.929 X 10^{-4}) X (sum of skinfold sites)] + [(2.3 X 10^{-6}) X (sum of skinfold sites squared)] − [1.392 X (10^{-4}) X (age of the subject to the nearest year)].

$$\text{Body Fat Percentage} = \frac{495}{\text{body density}} - 450.$$

The mean body fat percentages for each subject, both pre- and posttraining, were used for the data analysis.

Graded Exercise Test

Prior to the graded exercise test (GXT), subjects were given an information sheet which included the instructions to be carried out prior to each experimental trial (Appendix E). Verbal explanation of the following points was given to each subject prior to each GXT:

1. Wear appropriate attire for exercising.
2. Get adequate sleep the night prior to GXT.
3. Do not eat within 4 hr before testing.
4. Do not drink coffee or tea on the test day.
5. Do not smoke on the test day.
6. Do not engage in moderate to intense exercise within 24 hr prior to the test.

Subjects completed an informed consent form for the GXT (Appendix F) and test day information (Appendix G) upon arrival at the lab for the GXT. The GXT was conducted according to guidelines established by the American College of Sports Medicine (1986). Briefly, the subject rested in a supine position for 10 min prior to testing. At that time, resting values of BP and HR were obtained. The GXT was done on a Jaeger Ergotest cycle ergometer (model ER-40). The ergometer was programmed at 25 watts, increasing 25 watts every 2 min until VO_2 max was obtained or the subject could no longer maintain the pace specified by the protocol. HR and BP were taken 1 min into each stage. VO_2 was monitored at 30-s intervals by rapid gas analyzers (Applied Electrochemistry S-3A oxygen analyzer, Beckman LB-2 carbon dioxide analyzer) and a gas meter (Rayfield RAM-9200) interfaced with an Apple IIe computer system.

Peak VO_2, the highest value obtained for VO_2 during the GXT on the cycle ergometer, was used to design an exercise program for each subject in the experimental group. The results from the GXT were also used to establish if a training effect occurred over the training period. Estimated VO_2 max for each subject was determined from the workload of the GXT and the subject's body weight.

Estimated VO_2 max was derived using the following formula:

$$\underset{(ml/min)}{\text{Est. } VO_2} = \underset{(kpm/min)}{(\text{workload} \times 2)} + (3.5 \times \underset{(kg)}{\text{body weight}}).$$

The following formula was used to convert watts into kpm/min:

$$6.12 \text{ kpm/min} = 1 \text{ watt}.$$

Training Protocol

The 6 subjects in the experimental group trained on Monark cycle ergometers three times a week for 8 weeks. The workload was established using each individual's pretraining GXT peak VO_2. Percentages of peak VO_2 were calculated for 60%, 70%, 75%, and 80% of peak VO_2. A training schedule was established in which the subjects began at a workload of 60% of their peak VO_2 for 20 min the 1st week and gradually increased the workload or time each week until 80% of peak VO_2 for 50 min was reached by the 8th week (see Table 1). Adjustments were made in the training schedule to ensure each subject in the experimental group trained at three different workloads during the training period.

Data Analysis

ANOVAs were performed on the BMR and the VO_2 data collected to examine differences between the experimental group and the control group and changes across the time factor. The assumption of no interaction of groups by time was tested first. If the means of both groups over time

Table 1

Training Protocol

Week (#)	Peak VO_2 (%)	Time (min)
1	60	20
2	70	20
3	70	30
4	70	35
5	70	40
6	75	40
7	75	50
8	80	50

followed the same pattern, the assumption was met and change over time and differences between groups posttraining could be analyzed to determine if statistically significant differences existed.

A significance level of .05 was used as the criterion for rejecting the null hypotheses.

Summary

This investigation looked at the effects of 8 weeks of aerobic training on the Monark cycle ergometer on the BMR of 6 untrained females 20-30 years of age from the Ithaca College community. In addition to the 6 females participating in the experimental group, 5 females ages 20-30 years old from the Ithaca College community served as controls. Each subject had two VO_2 tests to determine her mean BMR prior to GXT. At the same time as the BMR measurements were taken, skinfold measurements were also recorded to determine the subject's body composition. From the GXT results an exercise prescription was designed for each subject in the experimental group. At the end of the 8 weeks of training a second GXT was performed by both the experimental and the control groups. Three days following the GXT a series of two more VO_2 tests for BMR were conducted along with skinfold measurements to determine the subject's body fat percentage. The data were analyzed using

ANOVA to examine the statistical significance of the change over time for both groups and difference between groups at the .05 level of significance.

Chapter 4

RESULTS

This study was conducted to investigate the effects of 8 weeks of aerobic training using a cycle ergometer on the BMR of females between 20 and 30 years of age. Specific variables examined were BMR, peak VO_2, peak watts (responses to a cycle ergometer GXT), and body fat percentage. The experimental group and the control group consisted of 6 and 5 female subjects, respectively. In this chapter the results will be presented in the following sections: basal metabolic rate, responses to GXT, and body fat percentage.

Basal Metabolic Rate

BMR results for each trial and for the average of pre- and posttraining for each subject are presented in Table 2. As noted, data out of range (> 2 SD from M) were replaced with the mean for that group of subjects during that time period. The F test for the group by time (pre- and posttraining) interaction revealed no significant interaction, $F(1, 9) = 0.43$, $p > .05$. Therefore, BMR followed the same pattern over time for both the experimental group and the control group. Because no significant two-way interaction was found, the main effects were analyzed. Pre- and posttraining BMR means between groups were nearly the same, $F(1, 9) = 0.00$, $p > .05$.

Table 2

Basal Metabolic Rate Before and After Training

	Pretraining			Posttraining		
	Trial 1	Trial 2	M	Trial 1	Trial 2	M
Experimental Group						
Subject						
1	43.51	40.21	41.86	44.97	24.87	34.92
2	39.95[a]	34.27	37.11[b]	40.96	43.21	42.09
3	27.35	36.74	32.05	34.99	36.08	35.54
4	44.13	38.90	41.52	23.38	32.63	28.01
5	42.56	48.62	45.59	32.02	36.93	34.48
6	40.18	42.98	41.58	36.94	36.81	36.88
M			39.95			35.32
SE			4.71			4.53
Control Group						
Subject						
1	38.35	38.22	38.29	33.65	35.97	34.81
2	41.91	47.10	44.51	40.51	37.87	39.19
3	34.25	38.81[a]	36.53[b]	35.17	34.86	35.02
4	38.61	38.81[a]	38.71[b]	37.86	36.49[a]	37.18[b]
5	33.22	38.81[a]	36.02[b]	37.39	35.09	36.24
M			38.81			36.48
SE			3.38			1.79

Note. All values of BMR are in kcal/m^2/hr.

[a]Out of range (M ± 2 SD) value replaced with mean for both trials during that time period for that group of subjects. [b]The mean is affected by the replacement of the mean of the group for one trial.

The means were 37.64 ± 5.04 for the exercise group and 37.65 ± 2.83 for the control group. It is apparent by looking at the means that some change occurred for each group over time, but the means of the two groups combined did not decrease a significant amount, $F(1, 9) = 3.93$, $p > .05$. Therefore, the null hypothesis was not rejected.

Responses to GXT

Peak VO_2

The highest value obtained for each subject during the GXT on the cycle ergometer was used for the analysis of peak VO_2. Data were considered out of range if the actual VO_2 value recorded was greater than two standard deviations from the estimated VO_2. The treatment of out-of-range data in this case was done by calculating the value of the standard deviation for each group and each trial, then adding or subtracting one standard deviation from the mean, depending on whether the actual value recorded was above or below the estimated VO_2 for that subject. Table 3 shows the values used for the data analysis on the peak VO_2.

Upon examination of the group by time interaction, no significant interaction was found, $F(1, 9) = 0.98$, $p > .05$. The assumption that the mean for each group over time responded in the same pattern was met, therefore the main effects could be analyzed.

Table 3

Aerobic Fitness Levels Before and After Training

	Pretraining			Posttraining		
	Peak VO_2	Est. VO_2[b]	Peak Watts	Peak VO_2	Est. VO_2[b]	Peak Watts
Experimental Group						
Subject						
1	34.00[a]	33.14	175	42.75	42.84	250
2	26.77	24.50	125	29.46	31.80	175
3	31.20	24.44	125	31.32	32.54	175
4	28.68	25.04	100	36.20	36.40	150
5	32.95	29.10	125	35.36	34.27	150
6	28.92	32.04	150	30.85	35.89	175
M	30.42	28.04	133.3	34.32	35.62	179.1
SD	2.77	3.94	25.8	4.91	3.97	36.8
Control Group						
Subject						
1	49.25	47.40	225	50.86	52.91	250
2	35.57[a]	27.50	125	39.30	41.83	200
3	42.16	44.64	225	49.85	47.21	250
4	49.89	39.57	225	46.26	44.07	250
5	38.75	39.75	175	37.17	38.15	175
M	43.12	39.77	195.0	44.69	44.83	225.0
SD	6.33	7.62	44.7	6.18	5.59	35.3

Note. VO_2 is in ml/kg/min.

[a]Data that were more than two standard deviations from the estimated VO_2 were replaced by the value of *M* ± 1 *SD* (for that group and trial).

[b]Est. VO_2 is estimated VO_2 max = (workload [kpm/min] X 2) + (3.5 X body weight [kg]).

There was a significant main effect for peak VO_2 between groups, $F(1, 9) = 16.20$, $p < .05$. The mean for the control group for this variable ($M = 43.12$) was higher than the mean for the experimental group ($M = 30.42$). This appears to be a result of a difference in prior training. The control group consisted of individuals who were trained prior to the beginning of this study, and the experimental group contained individuals who were untrained at the onset of the study.

The investigation of change across time also revealed a significant difference, $F(1, 9) = 5.33$, $p < .05$, indicating an improvement in peak VO_2 for both groups. Because the group by time analysis indicated no significant change, normally the time effect would just be interpreted as both groups' VO_2 improved significantly. However, when the means were graphed, the slopes appeared quite different, so an ANOVA for each group was run. It appears that the significant change across time was due to the significant change in the experimental group. When the analysis across time was done for each individual group, the experimental group showed a significant difference over time, $F(1, 5) = 7.82$, $p < .05$, but the control group showed no statistically significant difference over time $F(1, 4) = 4.26$, $p > .05$. The significant increase in peak VO_2 for the experimental group indicated there was a training effect for only this group of subjects.

Peak Workload

Analyzing peak workload obtained during the GXT revealed results similar to those for actual VO_2. Values for peak workload (in watts) for both groups can be seen on Table 3. There was no significant interaction of group by time, $F(1, 9) = 1.29$, $p > .05$. Because the assumption that the means for each group responded in the same pattern over time was met, the main effects could be analyzed.

There was a significant main effect recorded for peak workload between groups, $F(1, 9) = 29.59$, $p < .05$. The mean for the control group for this variable ($M = 225.00$) was higher than the mean for the experimental group ($M = 179.17$). This also appears to be the result of a difference in training status at the time this study began. The investigation of change across time also revealed a significant difference, $F(1, 9) = 6.85$, $p < .05$, indicating an improvement in peak workload for both groups.

Estimated VO_2 Max

Estimated VO_2 max was determined using the formula suggested by the American College of Sports Medicine (1986). This formula takes into account the subject's weight and the peak workload obtained during GXT. Values for the estimated VO_2 max for each subject can be seen in Table 3. The analysis on the estimated VO_2 illustrated there was no significant interaction of group by time. Therefore, the assumption was met that the changes that occurred in workload over time followed the same pattern for both groups, $F(1, 9) = 0.88$, $p > .05$.

There was a significant main effect recorded for estimated VO_2 max between groups, $F(1, 9) = 12.63$, $p < .05$. Again, this appears to be a result of a difference in training status at the onset of this study. The mean for the control group for this variable ($M = 44.83$) was higher than the mean for the experimental group ($M = 35.62$). The investigation of the change across time also revealed a significant difference, $F(1, 9) = 22.31$, $p < .05$, indicating an improvement in estimated VO_2 max for both groups.

Body Fat Percentage

Skinfold measurements were taken immediately following each BMR measurement. Missing data were dealt with by substituting the value of the mean for that group of subjects for both trials within that time period. Table 4 presents the body fat percentage of each subject for each trial. When body composition was first analyzed for an interaction of group by time, the extremely small value, $F(1, 9) = 0.04$, $p > .05$, may have been an indication of not meeting the assumptions of the ANOVA of either normal distribution or homogeneity of variance. Therefore Hartley's F max test was used to investigate this. The

Table 4

Body Fat Percentage Before and After Training

	Pretraining			Posttraining		
	1st	2nd	M	1st	2nd	M
Experimental Group						
Subject						
1	32.90	28.90	30.90	34.20	31.90	33.05
2	32.20	33.32	32.76	29.16	30.73	29.96
3	37.50	24.12	30.81	31.19	31.70	31.45
4	30.83	27.90	29.37	26.98	22.60	24.79
5	30.46	30.94	30.70	23.62	21.73	22.68
6	29.90	30.20	30.05	28.50	29.30	28.90
M			30.77			28.47
SE			1.14			3.98
Control Group						
Subject						
1	25.96	25.42	25.69	19.76	23.14	21.45
2	31.80	23.30	27.55	28.77	26.75	27.76
3	26.85	31.24	29.05	25.39	24.72	25.06
4	31.15	27.65[a]	29.40	27.62	29.42	28.52
5	28.82	24.27	26.55	25.64	26.08	25.86
M			27.65			25.73
SE			1.59			2.77

[a]Missing data were replaced by the mean for that group of subjects for that time period.

resulting value, $F(5, 5) = 3.16$, $p > .01$, was nonsignificant, indicating that homogeneity of variance of the raw scores could be assumed. The possibility still existed that there was a violation of the normality assumption, therefore, square roots of the average body fat percentages were used for the data analysis.

Interaction between the groups was not significant once the square roots of the values were used in the analysis, $F(1, 9) = 0.03$, $p > .05$. The main effect between groups was not significant, $F(1, 9) = 4.73$, $p > .05$, indicating no difference between groups with regard to body composition.

When the analysis was applied to compare the main effect of time upon body composition, it revealed a significant difference, $F(1, 9) = 5.26$, $p < .05$, indicating a change in mean body fat percentages over time for both groups. When examining each group individually over time, the investigation of the experimental group across time revealed there was no significant change, $F(1, 5) = 2.37$, $p > .05$. The control group also showed no significant change in body composition, $F(1, 4) = 4.26$, $p > .05$. A Tukey test failed to identify a difference when the groups were analyzed separately. The inability to find a difference seems to be due to the smaller degrees of freedom than when the means of both groups were taken together.

<u>Summary</u>

The means for BMR for both groups combined were not significantly different over the 8-week training period. Also, BMR means between the experimental group and the control group showed no significant difference. Therefore, the null hypothesis was not rejected. Training three times a week for 8 weeks on a Monark cycle ergometer at 60-80% peak VO_2 had no effect on BMR as measured by indirect calorimetry in women between the ages of 20 and 30 years.

Analysis of the responses to the GXT revealed a significant difference between the control group and the experimental group. This difference may be due to the difference in training states of the two groups prior to the beginning of this study. When examining the change in VO_2 across time for the mean of both groups combined, a significant increase in VO_2 was seen. When analyzing each group separately, the experimental group showed a significant change across time, and the control group showed no significant difference across time. This indicated there was a training effect for the experimental group after 8 weeks of training on a Monark cycle ergometer, while there was no statistically significant change in training levels for the control group.

The analysis of body fat percentages revealed there was no significant difference between the two groups of subjects. Also, there was no significant difference in body composition over the course of the study for both groups combined. This was also found when each group was analyzed separately.

Chapter 5

DISCUSSION OF RESULTS

This investigation studied the effects of 8 weeks of aerobic exercise training on basal metabolic rate (BMR). Acquiring knowledge of any effect of exercise upon BMR would be helpful in understanding the role of exercise in proper weight control. The results of this investigation are discussed in this chapter.

This investigation found there was no significant ($p > .05$) change in BMR as measured by indirect calorimetry as a result of 8 weeks of training on a cycle ergometer in women between the ages of 20 and 30 years. Therefore, the null hypothesis failed to be rejected. These findings are not in agreement with the studies of Bender (1951), Morehouse (1937), and Nielsen (1950) who all reported a rise in BMR following exercise training. Bender (1951) designed a program of physical activity (e.g., bicycling, running, swimming, playing handball, or playing basketball) specifically for each untrained subject. Morehouse (1937) studied the BMR of college athletes in and out of training over a period of a year, and Nielsen (1950) examined the changes in BMR of women taking college freshmen swimming classes. However, the subjects were not tested for a statistically significant change in fitness level following training in any of these studies. Therefore, it is unclear whether the increases in BMR in these studies were due to a training effect or other factors. Therefore, the apparent discrepancies between the present study and Bender (1951), Morehouse (1937), and Nielsen (1950) are difficult to explain.

In a study where training levels were tested, Tremblay, Fontaine, and Nadeau (1985) revealed that highly trained athletes (training 12-16 hr per week) had a significantly higher BMR than moderately trained (training 6-10 hr per week) and nontrained individuals. This was concluded to be an adaptive response because highly trained individuals use and store substrates differently than moderately trained and untrained individuals. In the present study, the experimental group only exercised three times a week for 50 min for the last 2 weeks of the training period. Even though there was a significant increase in VO_2 ($p < .05$), which indicated a training effect occurred, this training effect may not have been great enough to elicit a change in BMR. The mean posttraining peak VO_2 of the subjects in the present study was much lower than that of the highly trained athletes reported by Tremblay, Fontaine, and Nadeau (1985). In the present study posttraining peak VO_2 for the experimental group was 34.32 ± 4.91 ml/kg/min, which is below the fitness level LeBlanc, Mercier, and Samson (1984) and Tremblay et al. (1983) reported for moderately trained individuals. LeBlanc, Mercier, and Samson (1984) reported the untrained female subjects had a VO_2 max of 38.9 $\pm$ 1.47 ml/kg/min, and Tremblay et al. (1983) reported the nontrained subjects had a VO_2 max of 47.7 $\pm$ 1.70 ml/kg/min. Other studies that have reported a greater BMR in highly trained athletes over moderately trained individuals reported the highly trained athletes' VO_2 max to be 57.5 $\pm$ 0.95 ml/kg/min (LeBlanc, Mercier, & Samson, 1984) and 69.2 $\pm$ 2.00 ml/kg/min (Tremblay et al., 1983), yet the moderately trained subjects had a VO_2 max of 49.9 $\pm$ 0.81 ml/kg/min (LeBlanc, Mercier, & Samson, 1984) and 47.7 $\pm$ 1.70 ml/kg/min (Tremblay et al., 1983). Therefore, the subjects in the present study were not at the same fitness level as the highly trained athletes who showed an increase in BMR in previous studies. However, the direct comparison of VO_2 max among these studies can not be made because it was tested on a treadmill, whereas a GXT on a cycle ergometer was used in the present experiment. A cycle ergometer tends to yield a lower peak VO_2 than that obtained on a treadmill due to leg fatigue experienced during cycling (Lamb, 1984). Additionally, comparisons between the studies is difficult because Tremblay et al. (1983) and Tremblay, Fontaine, and Nadeau (1985) used male subjects, whereas the subjects in the present study were females, and it is well established that males tend to have a higher VO_2 max than females

(Lamb, 1984). Increasing the intensity level and duration of training may have revealed similar results to Tremblay, Fontaine, and Nadeau (1985), however, this possibility awaits further investigation. It is interesting that the studies by Bender (1951), LeBlanc, Mercier, and Samson (1984), Morehouse (1937), Nielsen (1950), and Tremblay, Fontaine, and Nadeau (1985), which showed an increase in BMR with training, did not report the time period elapsed between the last bout of exercise and when BMR was tested. Therefore, increases in BMR reported may represent an acute effect of exercise on BMR rather than a chronic effect.

Hermansen et al. (1984) revealed that some acute metabolic responses to intense exercise may take as long as 48 hr to return to preexercise values. For example, resynthesis of glycogen and protein during recovery requires ATP and VO_2 beyond the requirements to repay oxygen debt. Thus, there is an increase in VO_2 during this recovery time. This investigation was designed to study the chronic effect of aerobic exercise training, therfore, BMR was measured 72 hr postexercise. This study revealed there was no long lasting chronic effects of increasing BMR by aerobic exercise training to aid in weight control. However, exercising to acutely increase BMR and in turn increasing the energy expenditure (EE) side of the energy balance equation up to 48 hr postexercise does seem to be possible (deVries & Gray, 1963; Finch, 1978; Hermansen et al., 1984). Therefore, according to these previous studies, exercise training would increase BMR due to a long lasting acute effect.

In a study similar to the present investigation (Evans, 1986), it was found that BMR was significantly lower at the end of 8 weeks of exercise training for the exercise group. However, there was not a significant change in VO_2 max, therefore the change in BMR could not be solely attributed to exercise training. It was concluded that the decline in BMR may have been contributed to by seasonal variations (e.g., spring going into summer). Yoshimura et al. (1966) found a climatic adaptation of BMR in Japanese subjects: as the seasonal temperatures became warmer BMR decreased. The results of the present study showed a decrease in BMR for both the experimental and the control groups, however, these changes were not statistically significant ($p > .05$). Seasonal variations may be a factor in the observed decrease in BMR. The mean daily temperatures during the course of the study were as follows: February, 23.2 ^{o}F; March, 35.9 ^{o}F; April, 46.5 ^{o}F; and May, 58.8 ^{o}F. Therefore, the mean daily temperature increased over the course of this study, which may have affected BMR, although nonsignificantly.

Summary

In the present investigation it was found that aerobic exercise training had no statistically significant effect on BMR of women between the ages of 20 and 30 years of age. This may be because the final training level attained was not great enough to affect BMR. Several previous reports have shown BMR to be altered by chronic exercise when well-trained subjects were studied. Further investigation is needed to study the chronic effects of exercise on BMR for individuals at various levels of cardiorespiratory capacity. Seasonal variations (e.g., going from winter to spring) in BMR may be a factor in the statistically nonsignificant decrease in BMR for both groups over the training period.

Chapter 6

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

This study was conducted to investigate the effects of 8 weeks of exercise training using a cycle ergometer on basal metabolic rate (BMR) of untrained individuals. Two groups, an exercise group (n = 6) and a control group (n = 5) of females from the Ithaca College community between 20 and 30 years of age served as subjects.

Each subject participated in two indirect measurements of BMR using the open circuit technique for determination of VO_2 prior to training. Skinfold measurements to determine body fat percentages were taken following each of the BMR tests. A graded exercise test (GXT) was performed on a cycle ergometer by each subject prior to training to determine peak VO_2. The results of the GXT were used to design an individualized training program for each subject in the exercise group. Subjects in this group trained three times a week for 8 weeks on a Monark cycle ergometer. Posttraining measurements for all subjects were identical to those made pretraining.

ANOVAs were performed on the data collected to examine statistically significant differences existed. Analysis of the responses to the GXT revealed a significant difference between the exercise and control groups. This difference seems to be due to the difference in training levels of the two groups prior to the beginning of this study. When examining the change in VO_2 over the 8-week training period for both groups, there was a significant increase in peak VO_2 ($p < .05$). This increase in peak VO_2 for the means of both groups was due to a significant rise in peak VO_2 for the experimental group, as the control group showed no significant change ($p > .05$). Body fat percentages between the two groups showed no significant difference ($p > .05$). When body fat percentages across time were analyzed for both groups together, there was a significant decline in body fat ($p < .05$). However, once the two groups were analyzed separately for change over the training period, both the experimental and control groups were found to be not significant ($p > .05$). The means for BMR between the experimental and control groups for BMR showed no significant difference ($p > .05$). Also, the means for BMR for both groups were found to be not significantly different ($p > .05$) following the training period. Although it is possible that aerobic training may cause a change in BMR, the final training level attained in the present study (peak VO_2 = 35.32 ml/kg/min) may not be an adequate stimulus to induce a statistically significant change in BMR ($p > .05$) in young female subjects.

Conclusion

The results of this study yielded the following conclusion regarding the role of aerobic exercise training on BMR:

BMR did not significantly change after 8 weeks of exercise training at the training level in the present study on BMR. However, the nonsignificant decrease in BMR for both groups could indicate that other factors, such as seasonal variations, influence BMR.

Recommendations

The following recommendations for further study were made after the completion of this investigation:

1. A study similar to the present one should be conducted using untrained subjects as controls.

2. A study similar to the present one using two experimental groups exercising at different training levels should be conducted to examine the chronic effects of exercise upon BMR.

3. A study should be conducted examining the effects of weight training on BMR in order to investigate the effect increased muscle mass has on BMR.

Appendix A

RECRUITMENT LETTER

Ithaca College
School of Health, Physical Education, and Recreation

To: All women 18-30 years old

From: Vicki Tatro, Graduate Student
Dr. G. Sforzo, Assistant Professor, HPER

Re: Subjects for exercise physiology study needed

Date: January 1986

How would you like to become aerobically fit? Subjects are needed to participate in a research project studying the effects of aerobic training on basal metabolic rate. Basal metabolic rate is the caloric expenditure of an individual at rest, which is useful in determining caloric intake for weight control. Female subjects who are untrained and between 18 and 30 years old are needed. Through 8 weeks of exercise training, you can increase your aerobic endurance and muscle tone in your legs. You will also receive, at no cost, an evaluation of your aerobic endurance (graded exercise test, normally valued at $125.00) before and after the training, as well as your basal metabolic rate. The training and testing will commence in January 1986 and be completed by March 1986. Scheduling of training sessions can be done during lunch hours. What better way to shape up after the holidays and before bathing suit weather?

Aside from the personal benefits, your participation in this project will help define the relationship between exercise and basal metabolic rate, a critical factor to many in the struggle for weight control.

For more information, or if you are interested in being a participant in this study, please contact Vicki Tatro (257-2923) or Dr. G. Sforzo (274-3359). Your participation in this study would be greatly appreciated and beneficial to you.

Appendix B

MEDICAL QUESTIONNAIRE

Name:______________________ Age:______ Date:______

Check if YES

PAST HISTORY (in the past have you ever had?)

Rheumatic Fever	( )	Heart Murmur	( )
High Blood Pressure	( )	Rhythm Abnormalities	( )
Disease of Arteries	( )	Varicose Veins	( )
Lung Disease	( )	Injury to Back	( )
Epilepsy	( )	Diabetes	( )
Stroke/Heart Attack	( )	How long ago?______________	
Operations	( )	What kinds?______________	
Other	( )		

If other is checked explain here:________________________

FAMILY HISTORY (have any blood relatives had?)

Heart Attacks	( )	Heart Operations	( )
High Blood Pressure	( )	High Cholesterol	( )
Diabetes	( )	Congenital Heart Disease	( )
Other	( )		

If other is checked explain here:________________________

Appendix B (continued)

PRESENT SYMPTOMS (have you recently had?)

Chest Pain	( )	Shortness of Breath	( )
Heart Palpitations	( )	Lightheadedness	( )
Cough on Exertion	( )	Coughing up Blood	( )
Back Pain	( )	Arthritis	( )
Swollen Legs	( )	Loss of Consciousness	( )
Awaken Short of Breath	( )		

RISK FACTORS

1. Do you smoke? Yes ( ) No ( ) Quit ( )

   How long have you been smoking?________________________

   How many cigarettes do you smoke a day?________________

   If you quit, how many cigarettes did you smoke a day?_

   For how many years did you smoke?______________________

   When did you quit smoking?_____________________________

2. Have you gained ( ) or lost ( ) weight in the last 2 months? Yes ( ) No ( ) How much?____________________

3. Do you presently engage in physical activity?__________

   Descibe the nature and intensity.______________________

   ____

   How often?____

4. Is your occupation Sedentary ( ) Active ( )?

   Explain your occupation:_______________________________

   How far do you walk each day?__________________________

Appendix B (continued)

5. Do you have discomfort, shortness of breath, or pain with exercise? Yes ( ) No ( )

   If yes, what type of exercise:________________________

6. Are you taking any prescribed or over the counter medications regularly? Yes ( ) No ( )

   If yes, name the medications:________________________

7. Are you pregnant? Yes ( ) No ( )

   Are you trying to get pregnant? Yes ( ) No ( )

8. Have you had any major changes in your life within the last month (e.g., new job, change in marital status, birth of a baby)? Yes ( ) No ( )

<u>MEDICAL STATUS</u>

1. Have you had a medical exam in the last year?

   Yes ( ) No ( )

   When was your last medical exam?______________________

2. Do you or your physician know of any medical problems that may preclude your participation in an exercise study? Yes ( ) No ( )

Appendix C

QUESTIONNAIRE FOR AEROBIC FITNESS

History of Current Exercise Training

Name:__________________ Phone number:__________ Date:______

1. Do you currently exercise? If the answer is no, skip question numbers 2, 3, and 4 and go to question number 5. Yes ( ) No ( )

2. How many times do you exercise per week?_______________

3. What amount of time do you exercise per day? __________

4. What type of exercise you do (include examples as to the intensity of your training)?_____________________________

____

5. Did you ever engage in regular exercise? Yes ( ) No ( )

   How many times per week?________________________________

   What amount of time ?____________________________________

   How long ago did you cease this activity?______________

6. Do you or your physician know of any medical problems that may preclude your participation in an exercise study? Yes ( ) No ( )

Appendix D

INFORMED CONSENT FORM FOR STUDY

1. a. Purpose of the study. The purpose of this study is to investigate the effect of aerobic training on basal metabolic rate (BMR). BMR is the energy expenditure at rest after a 12-hour fast and a good night's sleep.

b. Benefits. By participating in this study you will receive 8 weeks of prescribed and supervised aerobic training. In addition, you will receive two free graded exercise tests to evaluate the improvement in your cardiovascular function as a result of training. These tests are normally valued at $125.00 each. You will also receive an evaluation of basal metabolic rate, which is useful in determining caloric expenditure for weight control. Aside from personal benefits, your participation in this project will help define the relationship between exercise training and BMR, a critical factor for many in the struggle for weight control.

2. Methods. You will be asked to give information on your current level of physical activity and medical status. As a subject, you will need to report to the Exercise Physiology Laboratory for the following sessions: 2 BMR testing sessions pretraining, 1 pretraining graded exercise test, exercise training sessions on the cycle ergometer three times each week for 8 weeks, 2 BMR

Appendix D (continued)

testing sessions posttraining, and 1 graded exercise test posttraining. The BMR test will consist of oxygen uptake being measured for 10 minutes in a supine resting position after a 12-hour fast and 30 minutes of undisturbed rest. Each BMR determination will take about 1 hour. The graded exercise test will be on the cycle ergometer to determine maximal exercise capacity. A complete graded exercise test should take about 1 hour. These tests will be administered according to the American College of Sports Medicine guidelines for graded exercise testing. The training sessions on the cycle ergometer will be 20 to 45 minutes in duration.

3. Will this hurt? Some muscle soreness in the legs may occur during the initial training phase of the study. This discomfort always accompanies the initiation of an exercise program, and relief occurs 5 to 8 days after beginning the training. The graded exercise testing involves maximal exercise, therefore risks associated with great exertion (e.g., muscular injury or compromised cardiovascular function) are possible but highly unlikely. No long-lasting physical or psychological risks are associated with your participation in this study.

4. Need more information? Additional information may be obtained from Vicki Tatro (257-2923) or Dr. G. Sforzo

Appendix D (continued)

(274-3359). All questions are welcomed and will be answered.

5. Withdrawal from the study. Participation is voluntary. Subjects are free to withdraw from this study at any time without prejudice of any kind.

6. Will data be maintained in confidence? Only the above named researchers will have access to these data. Complete anonymity will be maintained, and once the data are collected, names will be replaced by coded numbers. These coded numbers will be used instead of individual names for any subsequent reports.

7. I have read the above, I understand its contents, and I agree to participate in the study. I acknowledge I am 18 years of age or older. I have had a physical exam in the last year and do not know of any medical problems that may preclude participation in the exercise study.

____

Signature   Date

Appendix E

INSTRUCTIONS FOR SUBJECTS

The Effects of Aerobic Training on Basal Metabolic Rate

Instructions for Subjects

<u>General Information</u>:

1. <u>DO NOT</u> make changes in your exercise habits other than this exercise program during the course of the training and testing. Any change in your exercise routine other than the prescribed exercise will greatly affect the results of this study and could render your data unusable. Inform the tester of any noteworthy changes.
2. <u>DO NOT</u> make changes in your normal diet during the time frame of this study. Keep a diary of any changes in your normal diet. Any changes in your normal diet will greatly affect the results of this study and could render your data unusable. Inform the tester of any noteworthy changes.
3. Keep a diary of your menstruation during the course of the training and testing. Inform the tester of any noteworthy changes. Basal Metabolic Rate (BMR) is affected by where you are in your menstrual cycle.
4. Training and basal metabolism tests and graded exercise tests will be done in the Exercise Physiology Laboratory, room 23, Hill Center.

Appendix E (continued)

<u>Basal Metabolic Rate Test</u>:

1. Get adequate sleep the night before testing (8 hours).
2. <u>DO NOT</u> eat within 12 hours prior to testing. During those 12 hours <u>only</u> water is permitted. Eat a low protein meal the night before the test.
3. <u>DO NOT</u> drink coffee or tea on the day of the test.
4. <u>DO NOT</u> consume alcohol the night prior to testing.
5. <u>DO NOT</u> smoke on the day of the test.
6. <u>DO NOT</u> engage in moderate to intense exercise within 24 hours prior to the test, or unusually intense exercise 3 days prior to the test.
7. Report to the lab in the same manner each test day (e.g., do not walk one day and drive another day).
8. If you can not comply with any of the above please contact the tester.

<u>Graded Exercise Test</u>:

1. Bring proper exercising attire with you to the Exercise Physiology Laboratory.
2. Get adequate sleep the night before testing (8 hours).
3. <u>DO NOT</u> eat within 4 hours prior to testing. During those hours only water is permitted
4. <u>DO NOT</u> drink coffee or tea on the day of the test.
5. <u>DO NOT</u> consume alcohol the night prior to testing.

Appendix E (continued)

6. DO NOT smoke on the day of the test.
7. DO NOT engage in moderate to intense exercise during the 24 hours prior to the test.

Training on the Cycle Ergometer:

1. Bring proper exercising attire with you to the Exercise Physiology Laboratory.
2. Be sure to attend three training sessions per week during your scheduled time. If for any reason you are unable to come to the Exercise Physiology Laboratory during the assigned time, call Vicki Tatro at 257-2923 or 274-3359 to reschedule a time to exercise to fulfill the time needed per week for aerobic training to occur. Improvements in aerobic fitness and cardiovascular health are only attained with a minimum of three training sessions per week.

Appendix F

INFORMED CONSENT FORM FOR THE GRADED EXERCISE TEST

Modified from ACSM (1986) forma

1. <u>Explanation of the Exercise Test</u>:

You will perform an exercise test on a cycle ergometer. The exercise intensity will begin at a level you can easily accomplish and will be advanced in predetermined stages. We may stop the test at any time because of signs of fatigue, or you may stop when you wish because of personal feelings of fatigue or discomfort.

2. <u>Risks and Discomforts</u>:

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorder of the heart beat, and in rare instances, heart attck or death. Every effort will be made to minimize these through the preliminary examination and by observations during testing. Emergency equipment and trained personnel are available to deal with unusual situations that may arise.

3. <u>Benefits to be Expected</u>:

The results obtained form the exercise test will assist in evaluating your cardiovascular function and assist in our research.

4. <u>Inquiries</u>:

Any question about the procedures used in the exercise

Appendix F (continued)

test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations.

5. Freedom of Consent:

Your permission to perform this exercise test is voluntary. You are free to deny consent if you so desire.

I have read this form and I understand the test procedures that I will perform. I consent to participate in this test.

____

Signature of Subject

________________ ________________________

Date Witness

Questions: ____

____

Response: ____

____

[a] American College of Sports Medicine. (1986). Guidelines for exercise testing and prescription (3rd ed.). Philadelphia: Lea & Febiger.

Appendix G

TEST DAY INFORMATION

Name:______________________________ Date:__________

Time:______________________________

How much sleep did you get last night? (please circle one)

1 2 3 4 5 6 7 8 9 10 (hours)

How much sleep do you normally get? (please circle one)

1 2 3 4 5 6 7 8 9 10 (hours)

How long has it been since your last meal or snack? (please circle one)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 (hours)

List the items eaten below:

____

When did you last:

Have a cup of coffee or tea?______________________

Smoke a cigarette, cigar, or pipe?________________

Take drugs (including aspirin)?___________________

Drink alcohol?____________________________________

Give blood?_______________________________________

Have an illness?__________________________________

Suffer from respiratory problems?_________________

What sort of physical exercise did you perform yesterday?

What sort of physical exercise did you perform today?

Appendix G (continued)

Describe your general feelings by checking one of the following:

____Excellent	____Bad
____Very, Very Good	____Very Bad
____Very Good	____Very, Very Bad
____Good	____Terrible
____Neither Bad nor Good	

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