1986

The effects of exercise training on basal metabolic rate

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THE EFFECTS OF EXERCISE TRAINING ON BASAL METABOLIC RATE

A Thesis Presented to the Faculty of
the School of Health, Physical
Education, and Recreation
Ithaca College

In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by
Pamela Sue Evans

May 1986

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An Abstract

of a thesis 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

May 1986

Thesis Advisor: Dr. G. A. Sforzo

ABSTRACT

This study investigated the effects of exercise training on basal metabolic rate (BMR). The subjects were 12 Ithaca College female students and faculty members, aged 19-30 years. Each subject had her BMR measured twice prior to training by indirect calorimetry. Subjects performed a pretraining graded exercise test (GXT) on a bicycle ergometer to determine VO_2max. An 8-week exercise training program was designed for each subject from the determined VO_2max. Following training, measurements identical to those made prior to training were taken. Data obtained from the pretest and posttest were examined for significant differences using a repeated measures $\underline{t}$ test. It was determined that BMR decreased significantly ($\underline{p}$ <.05) following 8 weeks of exercise training. The difference in means between pre- and posttraining BMR was 5.29 cal/m^2/hr. VO_2max increased in 6 of the 12 subjects and decreased in 4 of the 12, however these changes did not indicate a significant training effect. The remaining 2 subjects were used as a control group. Factors other than training, such as hormonal or environmental influences, may help explain the observed decrease in BMR.

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Pamela Sue Evans

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.

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Date: April 23, 1986

ACKNOWLEDGMENTS

The investigator would like to thank everyone who made this study a reality.

1. To Dr. Gary Sforzo, for his guidance and help given to me throughout the testing and writing of this thesis.

2. To Dr. Pat Frye, for her suggestions and time.

3. To Sue, for her help in testing my subjects.

4. To my subjects, for their time, cooperation, and dedication.

5. To Penny, Jackie, and Linda, for their encouragement and friendship that kept me going during the year. Thanks for the memories.

DEDICATION

This thesis is dedicated to my parents, who gave me love, support, and encouragement throughout the year. Their belief in me allowed me to broaden my horizons and pursue a meaningful goal. Thanks for 25 years of caring, happiness, and love.

TABLE OF CONTENTS

LIST OF TABLES

Chapter I

INTRODUCTION

It is well known that obesity is a major health problem in America today. In 1982, it was estimated that one out of every five adults, or 34 million Americans, could be considered obese ("Fear of Fat," 1985). This serious problem could possibly be remedied by the apparently simple regulation of caloric intake and caloric expenditure. Caloric intake is the amount of calories consumed during a day, while caloric expenditure is the amount of calories burned to produce energy for the body. Although caloric intake is simply related to food ingested, energy expenditure is a function of three factors: daily activities, specific dynamic action of food (SDA), and basal metabolic rate (BMR). The first factor involves those calories expended during daily activities (e.g., talking, walking, eating) above basal level. The second factor, SDA, increases energy expenditure after food ingestion due to the thermic effect of food. BMR, the third factor, is the minimal energy required to maintain the vegetative, circulatory, and respiratory functions in the waking state and accounts for three-fourths of the total caloric expenditure (Miller, 1982; Shepro & Knuttgen, 1979).

In assessing caloric expenditure, physical exercise is a special type of daily activity that contributes to total caloric expenditure and is useful in the struggle that many face while attempting to control their weight. According to some reports (Blaza & Garrow, 1983; Gleeson, Brown, Waring, & Stock, 1982; Zahorska-Markiewicz, 1980), exercise may further affect caloric expenditure by altering the SDA. Another impact exercise may have upon caloric expenditure is to alter BMR. Whether habitual exercise increases, decreases, or has no effect on BMR is undetermined. It is the purpose of this study to determine the effect of an 8-week exercise training program on BMR.

Scope of Problem

An 8-week physical training program was established for 12 college-aged female subjects to study the effects of exercise on BMR. Their weekly workouts consisted of riding a bicycle ergometer at workloads determined by a percentage of their maximum oxygen consumption (VO_2max).

Subjects completed two basal metabolism tests prior to training. These results were averaged to obtain a reliable estimate of BMR. A pretraining graded exercise test (GXT) was performed to determine the subject's initial VO_2max. Following 8 weeks of training, two basal metabolic measurements were again taken for comparison to pretraining values. Furthermore, a posttraining graded exercise test (GXT) was performed to assure training was indeed sufficient to increase VO_2max.

Statement of Problem

Does 8 weeks of aerobic exercise training change BMR as determined by indirect calorimetry using the open-circuit method?

Null Hypothesis

Physical training on a bicycle ergometer for 8 weeks has no effect on BMR as determined by indirect calorimetry using the open-circuit method.

Definitions of Terms

The following terms have been defined for the purpose of this study:

1. Basal metabolic rate (BMR): The magnitude of heat production in the postabsorptive state during complete physical rest in a comfortable, warm environment. This represents the minimal energy requirements necessary to maintain the vegetative, circulatory, and respiratory functions in the waking state (Shepro & Knuttgen, 1979).

2. VO_2max: An individual's capacity to use oxygen during physical exercise, recorded in milliliters (per kilogram body weight) of oxygen utilized.

3. Untrained individual: An individual who has not participated in any vigorous or habitual aerobic activity for at least 1 month prior to testing.

Delimitations of Study

The following delimitations were appropriate for this study:

1. Untrained female subjects (N = 12) between the ages of 19 and 30 years were utilized as subjects in the study.

2. Two BMR measurements were taken to get an average BMR prior to training. After training, an average BMR was determined in the same manner.

3. Training extended over a period of 8 weeks with a minimum of 3 days of bicycle training per week.

4. A bicycle ergometer was used for testing and training.

5. Spring and summer were chosen as the seasons during which to perform the study.

6. Room conditions for testing were as follows: room temperature 20-25°C, barometric pressure 737-740 mmHg, and relative humidity 40-45%.

Limitations of Study

The following limitations existed for this study:

1. Basal measurements may give an average measurement that is dependent on exercise and food intake the day prior to testing. Therefore, these measurements could be inaccurate.

2. The initial GXT on the bicycle ergometer may underestimate the subjects' VO_2max as a result of test termination due to leg fatigue. Therefore, the subjects' training programs may not have been as intense as they should

have been to produce the desired results. Any improvements seen might be improvements in leg muscle endurance rather than an increase in actual VO_2max.

3. The results of this investigation only apply to untrained females between the ages of 19 and 30.

4. The results of this investigation only apply to training on a bicycle ergometer.

5. BMR measurements may depend on variations seen between spring and summer months.

6. The results of this investigation only apply to BMR measurements acquired in similar room conditions (i.e., room temperature 20-25°C, barometric pressure 737-740 mmHg, and relative humidity 40-45%).

Chapter 2

REVIEW OF LITERATURE

The purpose of this investigation was to study the effects of exercise on BMR. Literature is limited in this area and controversial to some extent. Increased, decreased, and unaltered BMR have all been linked with exercise training. The literature dealing with factors that may affect caloric expenditure, particularly exercise training, will be reviewed in this chapter.

Factors Determining Caloric Expenditure

Caloric expenditure is the amount of calories burned and liberated as heat from the body. Alterations in caloric expenditure contribute to the regulation of energy produced by the body, which in turn affects weight control. This expenditure is the sum of calories consumed for daily activities, specific dynamic action of food, and BMR.

Daily Activities

Daily activities such as walking, talking, and eating require energy above the basal level. This energy is used by the muscles in doing work, mainly in moving the mass of the body and in part in doing external work (Davidson, Passmore, Brock, & Truswell, 1975). This daily energy requirement ranges from 1800 to 2700 kcal, and as one performs activities (e.g., walking up steps) energy expenditure increases. Some daily activities can result in total caloric expenditure increasing up to 3.5

times one's BMR (Guyton, 1976). In conjunction with the type of activity, body weight influences the gross metabolic cost of most activities (Godin & Shepard, 1973). Mahadeva, Passmore, and Woolf (1953) pointed out that metabolic cost is proportional to body weight only when a large proportion of energy expenditure is for physical activity. They also reported that in many industrial, domestic, and recreational activities, a major part of the metabolic cost is spent in moving the body. Therefore, weight is an important factor in determining metabolic cost. Further studies revealed that the gross body weight is less important in assessing the energy requirements of the occupation at lower levels of work intensity than in physically heavy work (Gleeson et al., 1982). In addition to daily activities affecting caloric expenditure, the thermic effect of food contributes to total caloric expenditure.

Specific Dynamic Action of Food

Obviously, food intake is associated with increased caloric consumption, but it also increases caloric expenditure. Increased energy expenditure because of an increase in metabolic rate after food ingestion is the result of the thermic effect of food or SDA (Zahorska-Markiewicz, 1980). This increase is associated with the chemical reactions of digestion. After eating a high fat or carbohydrate meal, metabolism increases 4%. After a large protein meal, metabolism increases

increases 30% within 1 hour after ingestion and stays elevated for 3-12 hours (Applegate, Upton, & Stein, 1984; Guyton, 1976; Zahorska-Markiewicz, 1980).

Diet-induced thermogenesis (DIT) is defined as the difference between the heat produced after the ingestion of a meal and the heat produced by BMR (LeBlanc, Mercier, & Samson, 1984). DIT results from a sympathetic activation of brown adipose tissue (BAT), a highly vascular form of adipose tissue with thermogenic activity. Rothwell and Stock (1983) studied energy balance and BAT metabolism on rats fed either a stock diet or a cafeteria diet. The diet of cafeteria fed rats consisted of highly palatable foods as compared to stock diet food. Results showed that hypertrophy of BAT occurred in all rats, however the greater amount of hypertrophy was seen in those rats fed the cafeteria diet. BAT has been shown to increase with dietary excess, in an attempt to dissipate calories as heat rather than store them as fat. This suggests its role in metabolic efficiency (Bray, 1983; Rothwell, Saville, Stock, & Wyllie, 1983). As a result of this increase, SDA makes a significant contribution to daily caloric expenditure. In addition to SDA and daily activities, BMR is a major contributor to caloric expenditure.

<u>Basal Metabolic Rate</u>

Basal metabolism is the energy needed for maintenance of life when an individual in the wakeful state is at digestive, physical, and emotional rest. This energy is required for cellular reactions needed to carry on vital life processes of the body (Darden, 1976). These life activities include beating of the heart, filtering activity of the kidneys, synthesis of large molecules from smaller ones, breathing movement of the chest, transmission of electrical impulses, and movement of material in and out of the cell (Runyan, 1976). These activities all require oxygen consumption (VO_2) to create the energy needed to allow for their completion, and they all cause heat release. BMR can be measured by direct or indirect calorimetry. Direct calorimetry involves measuring the energy expended by a subject inside a closed chamber that has walls specifically designed to absorb and measure the heat produced. Direct calorimetry is a more accurate means of measurement than indirect, however the elaborate apparatus presents serious restrictions on mobility (Bray, 1983). Indirect calorimetry estimates the energy expended by measuring the amount of O_2 consumed by the subject. This can be done because there is a direct quantifiable relationship between VO_2 and energy expenditure, in that for each liter of O_2 consumed, approximately 5 kcal of energy are produced. Therefore, energy expenditure of the body is the sum of energy requirements for daily activities, SDA, and BMR, but BMR is easily the major contributor and accounts for about three-fourths of our daily caloric expenditure (Miller, 1982).

Factors Affecting BMR

BMR represents the minimal amount of energy needed to maintain basic life processes. According to changes in energy and bodily demands, this rate changes and adapts as needed. Several factors, such as sex and age, weight and body surface area, chronic dietary changes, environmental changes, and hormonal changes affect basal metabolism and cause a change in this rate.

Sex and Age

BMR varies from individual to individual. Factors such as sex and age are known to affect BMR. Age has a great influence upon the metabolism of the body, particularly during the developing years. The highest rate of energy expenditure per unit of body surface occurs in infants, then there is a gradual decline in childhood, with a slower decline in adult life. After age 18, BMR declines 2% per decade for adults of both sexes (Bray, 1983). The results of a study by Benedict (1915) indicated that younger individuals have a higher metabolism than older individuals regardless of sex. He compared teenage boys and girls with men and women, aged 22-40 years, and found significantly higher metabolism in younger males. However, Durnin (1976) and Miller (1982) showed that women have a 5-7% lower BMR than men. Lower metabolic rates are seen in women than in men of comparable height and weight, primarily due to the higher body fat content of adult women. For females, a more constant BMR becomes apparent at 17-24 years of age (Pittman et al., 1943). Men also have a 10-15% higher BMR than women due to the presence of male hormones (Bray, 1983). Until age 4, no sex difference is seen in BMR. The difference is 1% after age 4, 2.5% at age 6, 3% at age 12, 8-9% at 15-16 years of age, and is reduced to 1% at age 20, 3% at age 30, and 4% at 40 (Durnin, 1976). After eliminating the effect of body weight, the difference at age 20 is unknown, but remains the same at ages 30 and 40. Clearly, sex and age are factors that can considerably affect BMR, even without considering the effects of body weight.

Weight and Body Surface Area

Obesity, which is associated with caloric imbalance and an accumulation of an abnormally large amount of fat, affects the energy expenditure of the body (Bradley, 1980). Gleeson et al. (1982) showed a linear relationship between energy expenditure and body weight. They further reported that obese people of both sexes had a higher energy expenditure than subjects of average weight during both basal and work periods. However, Blackburn and Calloway (1976) showed that BMR increased more than body weight during pregnancy and dropped slightly per unit mass near term. Pregnant women (*N* = 21) were studied from the 4th through the 9th month of pregnancy, and 16 were followed 8-12 weeks postpartum. Data on VO_2 and CO_2 production were recorded during basal, sitting, and standing activities after an overnight fast. Work tests were performed 30 minutes or more after a light snack. Standardized activities consisted of pedaling a bicycle ergometer and walking on a treadmill. Results showed BMR at 20-28 weeks of gestation was 21% higher than postpartum values for the same women. Values of body mass showed only a 13% difference in body weight at these two times. BMR increased another 15% during the last 20 weeks of gestation, paralleling body weight gain. However, in the last 4 weeks of gestation, body weight gain continued, yet BMR did not increase significantly.

BMR is also related to body surface area. Surface area refers to the body size of the individual and not to body weight. As body weight increases in relation to body size, there is a rise in metabolic rate. Therefore, heavier individuals require more energy for their resting metabolic needs (Bray, 1983). However, because of varying shapes and compositions, surface area may prove to be misleading in obese people (Davidson et al., 1975). Davidson et al. (1975) further explained that BMR is more closely related to lean body mass than to surface area. They stated that BMR figures expressed as lean body mass cancel the difference between men and women. Therefore, this does not reflect differences in metabolism, but reflects the fact that women are fatter and have metabolism variations due to this fact (Davidson et al., 1975).

Nutritional status of the individual is related to the total energy required by the body. Lamb (1984) emphasized that decreasing caloric intake decreased the BMR and also decreased body weight. With reduced caloric intake, sometimes the body adapts by reducing energy expenditure as much as 30%, thereby reducing BMR.

Chronic Dietary Changes

Both overeating and undereating for extended periods of time have an effect on BMR. The American College of Sports Medicine (1983) reported in a paper on proper and improper weight loss, that during a diet of restricted intake, thyroxine metabolism is altered and BMR reduced. Bray (1983) showed a decline in BMR during adaptation to reduced caloric intake. In this study, subjects' caloric intake was reduced in increments from 3500 kcal/day to 450 kcal/day over a period of approximately 32 days. A slow decline in body weight occurred, but BMR declined more rapidly. Bray proposed two mechanisms for this occurrence. The first was a decrease in L-triiodothyronine (T_3), a metabolic rate increasing hormone. Reports indicate that following food deprivation, a drop in serum concentration of T_3 is seen and, conversely, that overfeeding increases T_3 (Bray, 1983). Therefore, T_3 reduction may play a role in decreased BMR during starvation. Bray's second hypothesis stated that reduced activity of some metabolic tissue, which is dependent on stimulation from the sympathetic nervous system, could be responsible for the rapid decline in BMR in conjunction with the slow decline in body weight. A prominent example of this type of tissue is BAT, a metabolically active tissue that involutes with starvation and increases its activity with overfeeding (Bray, 1983). The Acheson, Jequier, Burger, & Danforth (1984) study supported Bray's first hypothesis by reporting increased T_3 in overfeeding and decreased T_3 in underfeeding, with parallel changes appearing in BMR.

Lammert and Hansen (1982) researched the chronic effects of excessive food intake and semistarvation. His study consisted of monitoring the subjects' intake for 6 weeks. During the first 2 weeks, subjects' food intake was not regulated and ranged from 2000-3200 kcal/day. During the second 2-week interval, their intake was increased by 2900 kcal/day over their habitual intake as displayed during the initial 2 weeks. The last 2 weeks, the subjects were semistarved on an intake of only 1500 kcal/day. Energy expenditure was measured by O_2 consumption during rest prior to exercise and following exercise. The results showed that energy expenditure increased with overeating and decreased with semistarvation under all conditions. However, the magnitude of increase or decrease varied among individuals. These studies confirm the fact that dietary changes have a definite effect on BMR.

Environment

Environmental variations affect the day-to-day metabolism of individuals. As factors in the external environment vary, BMR varies with them. Benedict's (1935) results showed that cold and warm weather affect the metabolism of birds and animals, but no reference was made to man. His results revealed a higher metabolic rate in January and a lower one in June. In a previous study done by Benedict (1915), BMR was observed on a human subject for 6 days in winter and again for 6 days in summer. Marked differences occurred, with the higher expenditure being in the winter (Benedict, 1915). A possible reason for a higher metabolism is an increased cooling of the body surface area. For example, with cooler temperatures, internal muscular work must increase to warm the body, therefore heat production and metabolism are increased. Additional results regarding seasonal variations associated with BMR are controversial.

Sunshine and humidity were shown to affect metabolism. Pittman et al. (1943) found in their 5-year study that BMR is directly proportional to seasonal temperatures. The subjects from warmer states had slightly lower basal rates than those from the colder regions. Davidson et al. (1975) discussed tropical regions and their relation to lowered BMR.

They also stated that most immigrants to these regions from Europe and North America show a significant drop in BMR. They concluded that low BMR of tropical races is due to environmental adaptations.

Seasonal changes in BMR were observed in various studies, however measurements were taken in climate controlled settings. The experimental room conditions must be kept between a temperature of 18-27°C, barometric pressure between 739-765 mmHg, and relative humidity approximately 45% (Bender, 1951; DiNucci, 1957). The room should be dimly lit and as quiet as possible.

Hormonal Changes

Hormonal variations have also been shown to increase BMR. If the thyroid is active, more thyroxine is produced, which subsequently can increase BMR by as much as a factor of 5 (Dubois, 1930; Shepro & Knuttgen, 1979). Thyroxine is a hormone secreted by the thyroid gland and is important in metabolic regulation. Varying concentrations of L-triiodothyronine (T_3), a potent thermogenic hormone, increase or decrease the BMR. A well established thermogenic effect of T_3 is that BMR increases with increased plasma concentrations of T_3 (Acheson et al., 1984). Hyperthyroidism results in large increases in metabolic rate, but hypothyroidism decreases energy expenditure (Rothwell et al., 1983). Furthermore, a lack of iodine, known to cause thyroid deficiencies, can lead to a decrease in BMR.

As mentioned above, fasting and low-caloric diets can cause changes in thyroxine metabolism. Overeating tends to increase T_3 production causing an associated increase in BMR. In contrast, a reduction of T_3 due to fasting causes a reduced metabolic rate. This reduction is in conjunction with reduced activity of the sympathetic nervous system (Acheson et al., 1984; Bray, 1983).

This influence of endocrine function on metabolic activity at a widespread tissue level can explain the difference between the BMR of men and women. Men have a slightly higher thyroid activity, leading to a higher BMR than in females (Durnin, 1976). Benedict (1915) also suggested males have more regular BMRs than females as a result of BMR variability associated with the female sex hormone variation during the menstrual cycle. Because of these variations, it is more difficult to establish normal BMR values for females. The 12-year study conducted by Benedict (1935) showed a 3.5% lower BMR during menstruation than on non-menstruating days. In addition, heat production was shown to increase during premenstrual and intermenstrual days (Dubois, 1930). Dubois (1930) also revealed a 2.7% higher metabolism just prior to menstruation than during menstruation. In agreement with Dubois' findings, Snell, Ford, & Rowntree (1920) found a constant rise in BMR during menstruation and during premenstrual periods, while a decline was seen during the postmenstrual period. The endocrine glands' secretion of hormones thus plays a role in the regulation of BMR.

Effects of Exercise on Caloric Expenditure

Exercise and training, to which the body has to physiologically adapt, increase total caloric expenditure. Therefore, daily activities, SDA, and BMR, which contribute to total caloric expenditure, may be affected to various degrees by exercise. This excess expenditure fluctuates depending on the type and duration of physical exercise performed.

Daily Activity

Clearly, exercise increases the daily activities portion of caloric expenditure. Additionally, regular physical exercise may produce improvements in cardiovascular function, muscular strength and endurance, ligament and bone strength, and flexibility (Lamb, 1984). As the body becomes trained, metabolic adaptations occur within the body. The activities of many enzymes involved in energy metabolism are greatly modified, and the patterns of storage and mobilization of energy reserves are altered. Greater efficiency of the body and improvements in its nutritive condition are also the result of physical training. There is a widespread opinion that if living cells are stimulated to increase activity through exercise, they will use more O_2, however if life processes become more efficient, they will use less O_2 (Schneider & Foster, 1931).

Specific Dynamic Action of Food

Several studies have been conducted to examine the effects of food in conjunction with exercise on BMR. Exercise immediately following a meal raises the thermic effect of food even when the energy cost of exercise is accounted for. In well-trained subjects, an increase in food utilization is seen, and a decrease in thermogenesis occurs. This reduction of thermogenesis is possibly due to an increase in food efficiency, which is seen as storing nutrients in the form of glycogen rather than fat (LeBlanc et al., 1984). This work was also supported by a study that showed metabolic response to a meal was higher in untrained subjects (210 kJ) than in trained (110 kJ) (Tremblay, Cote, & LeBlanc, 1983). This response of reduced energy utilization in the form of carbohydrates in trained subjects gives the idea that energy is preserved for the purpose of producing work. The significant correlation indicates that trained individuals oxidize a greater portion of lipids in the postprandial state (Tremblay et al., 1983). This reflects an exercise-induced sparing effect on carbohydrate utilization.

Basal Metabolic Rate

In respect to training and its effect on BMR, no definite relationship has been confirmed. Steinhaus (1929) stated that metabolic changes with training must happen gradually and continue for a reasonable time following training cessation. Maintenance of muscle tonus represents the chief oxygen requirement under basal conditions. In a study of 6 middle aged men put through 8 weeks of strenuous training, then 8 weeks detraining, followed by 8 weeks of training again, impressive decreases in BMR were seen (Cureton, 1969). The 8-week training program was a gradual progression starting with an initial 30 minutes of warm-up calisthenics, then 30 minutes of handball. The 8 weeks of detraining required the men to revert to their normal sedentary life and discontinue the training program. The second 8 weeks of training included the same activities as the first training period, but activities were more strenuous and were continued for longer periods of time.

Finch (1978) reported that lower BMR could be due to food intake, training intensities, rest conditions, and soreness in subjects. His study, representing an acute exercise effect on metabolism, involved 16 healthy college aged males performing a workout that included 5 bouts of running at 5 mph at a 5% grade for 5 minutes with a 1-minute rest between bouts. The BMR was measured at 2-, 4-, and 6-hour intervals on the days of exercise and on nonexercise days. On nonexercise days, subjects showed a lower BMR than on exercise days, however the only statistically significant difference was at the 4-hour interval. Therefore, literature reveals physical training can cause a decrease in BMR. On the other hand, Cureton (1969) discussed a few studies that showed an increase in BMR. Three endurance programs undertaken by middle-aged men, one a progressive exercise program, another a 6-week swimming experiment, and the third a 6-month dynamic health exercise program, showed increases in the BMR with training. The swimming experiment revealed a 7% increase in BMR, and the 6-month dynamic health exercise program showed a 43% increase in BMR.

Results concerning the effects of exercise on BMR also vary within a study. In one study, seven of nine athletes decreased their BMR with training, but one showed no change, and another increased his BMR. BMR was measured on each individual with the Benedict Field Respiration Apparatus before he arose in the morning. The athletes trained for the sport they participated in for the duration of the sport. Results could have been influenced by differences in the season during which training occurred and the number of months the athletes trained (Schneider & Foster, 1931).

Summary

Caloric expenditure is affected by factors external and internal to the body. BMR is the most significant factor involved in caloric expenditure, because it accounts for three-fourths of the total expenditure of the body. As an important contributing factor, BMR is itself affected by several factors. Studies have shown seasonal and hormonal changes to be the most influential. With ~~increased~~ decreased temperatures and increased hormonal secretions, BMR has been shown to increase. Even though some studies confirm this fact, other studies show just the opposite. Therefore, results are unclear as to the definite effect of each factor. In terms of total caloric expenditure of the body, exercise causes an increase above this total expenditure. Exercise increases the caloric expenditure response of daily activities and SDA, however BMR has been shown to increase, decrease, and remain unchanged with exercise. Literature reports various effects of exercise on BMR, therefore research needs to be done in this area.

Chapter 3

METHODS AND PROCEDURES

The following chapter considers the methods and procedures involved in this investigation. The following sections are addressed: selection of subjects, testing instruments, exercise training, methods of data collection analysis of data, and a summary.

Selection of Subjects

Subjects were 12 female Ithaca College students and faculty members between the ages of 19 and 30 years who participated in this study voluntarily. Two of the 12 subjects served as controls and did not participate in the training program. Each subject completed a data information sheet (Appendix A) and signed an informed consent form detailing procedures and purposes of the study (Appendix B). Only subjects who were classified as untrained (i.e., minimal physical activities during the 1 month prior to beginning the study) were allowed to participate.

Testing Instruments

Basal metabolic rate (BMR) was determined by indirect calorimetry using the open-circuit technique. Inspired air was measured using a Rayfield gas meter (model 9200), and VO_2 and VCO_2 were determined via rapid gas analyzers (Applied Electrochemistry SA-3 and Beckman LB-2) interfaced with an Apple IIe computer system. Body temperature was monitored with an oral thermometer, blood pressure with an anaeroid sphygmomanometer, and heart rate by palpating pulse at the radial artery. During all BMR measurements, room conditions were maintained at 24 ± 2°C, 43% ± 3% relative humidity, and 739 ± 9 mmHg barometric pressure. On the day of the graded exercise test (GXT), heart function was monitored during rest, exercise, and recovery by a Medical Systems Electrocardiograph (model MSC 7111) with an Exersentry unit interfaced for digital heart rate determination. Graded exercise testing (GXT) and training sessions were performed on a Monarch bicycle ergometer (model 850).

Exercise Training

The 8-week training program was prescribed from the results obtained during the GXT. The subjects began exercising at 60% VO_2max for 20 minutes and progressed to 80% VO_2max for 50 minutes by the 8th week of training. This progression is detailed in Appendix C. Subjects warmed up on the bike for 5-10 minutes prior to beginning each training session. Training frequency was 3 times each week during the 8-week period. All training was done on Monarch bicycle ergometers during times convenient for the subject. Regular contacts were made with the subjects by the experimentor to discuss training progress.

Methods of Data Collection

Subjects came to the Ithaca College Exercise Physiology

Laboratory twice prior to training and twice after training to measure BMR. Procedures were identical at each measurement session, both before and after the training period. Subjects arrived in the morning after a 12-14 hour fast and an 8-hour sleep, having not participated in vigorous physical activity on the previous day. Upon arrival at the lab, they rested in a supine position for a minimum of 30 minutes in a dimly lit room. Subsequently, BMR was measured for 6 minutes. During a separate visit, subjects also performed a GXT.

Graded exercise testing involved measuring the subject's maximum workload and VO_2max on a bicycle ergometer. ECG, HR, and BP were monitored prior to, during, and following exercise; expired air was sampled continuously during exercise. The exercise protocol involved starting at 150 kpm for a 2-minute warm-up and progressing by 150 kpm increments each 2 minutes until the subject reached her maximum workload. The protocol is detailed in Appendix D. Pedal cadence was established by a metronome set at 100 beats/min, and the subjects were instructed to ride at a rate of 50 rev/min. During the GXT, computer printouts of pertinent metabolic data (e.g., VO_2) were obtained. An example of this can be seen in Appendix E. The completion of the test was followed by supine recovery. Prior to release, the subject was monitored for a minimum of 8 minutes or until physical parameters returned to near pretest levels.

Analysis of Data

Repeated measures *t* tests were performed between pre- and posttraining values of BMR and VO_2max to determine if statistically significant changes had occurred.

Summary

Female Ithaca College students and faculty members (*N* = 12) under the age of 30 voluntarily participated in this investigation to examine the effects of 8 weeks of exercise training on BMR. Subjects trained on a bicycle ergometer a minimum of 3 days a week for 8 weeks. Basal metabolic rate was measured twice prior to training and twice posttraining to determine the effects of exercise. Statistical analysis involved using repeated measures *t* tests to identify changes in BMR and VO_2max over the 8-week training period.

Chapter 4

ANALYSIS OF DATA

The results of this investigation are presented in the following chapter. This chapter is divided into sections describing (a) characteristics of subjects, (b) results of a repeated measures t test on the basal metabolic rate (BMR) before and after training, and (c) results of a repeated measures t test on the VO_2max before and after training.

Characteristics of Subjects

The age, weight, height, body surface area, percentage of body fat, and maximum O_2 consumption (VO_2max) of the 10 female experimental subjects and 2 control subjects are given in Table 1. The average percentage of body fat for women ages 16-25 years is 25% (Lamb, 1984). All subjects fell below this value, suggesting that this group is atypical with regard to body composition. Subjects were generally untrained (mean VO_2max = 42.00 ml/kg/min), however two subjects had high beginning VO_2max values which may indicate a genetic predisposition toward high cardiorespiratory fitness for these subjects. The remaining four factors (i.e., age, weight, height, and body surface area) were typical for individuals of this age group and sex.

Repeated Measures t Test on BMR

Table 2 presents the results of a repeated t test on basal metabolic rate before and after training. The initial

Table 1

Characteristics of Subjects

	Experimental[a]		Control[b]	
	M	SD	M	SD
Age (yrs)	22.70	2.50	26.50	3.50
Weight (kg)	62.32	6.71	65.40	2.69
Height (cm)	167.90	7.64	159.34	7.71
Surface Area (m^2)	1.71	0.13	1.67	0.05
Body Fat (%)	19.35	4.66	25.60	3.90
VO_2max (ml/kg/min)	42.00	7.39	---[c]	---[c]

[a] n = 10.

[b] n = 2.

[c] VO_2max not measured in Control Subjects.

Table 2

Pre- and Posttraining Basal Metabolic Rates

	M	*SD*	*t*
Experimental			
Pretraining	42.02	3.45	5.29*
Posttraining	36.72	4.14	
Control			
Pretraining	47.21	4.99	2.53
Posttraining	40.34	1.15	

Note. All values are expressed in $cal/m^2/hr$.

*p < .05.

mean BMR for this group of women was significantly decreased following training ($p < .05$). For 9 of 10 subjects, BMR decreased with training. The average decrease was 13.88% for the 9 subjects. The 10th experienced no remarkable change in BMR after training.

Table 2 also presents the results of a repeated measures t test on the BMR of 2 control subjects who did not participate in the 8-week exercise training program. The mean BMR decreased following 8 weeks of routine daily activities, however this decrease was not statistically significant.

Repeated Measures t Test on VO_2max

Six of the subjects increased their VO_2max by an average of 15.65%, but the remaining four subjects decreased by 14.46%. For two of these four subjects, VO_2max decreased greatly, but for the others, the decrease was slight. When all subjects were combined, no significant difference was seen between VO_2max before and after training (Table 3).

Summary

BMR means were significantly lower ($p < .05$) at the end of 8 weeks of exercise training than before training. However, because no significant change was seen in VO_2max, the decrease in BMR can not be attributed solely to a training effect.

Table 3

Pre- and Posttraining VO_2max

	M	SD	t
Pretraining	42.00	7.39	0.58
Posttraining	43.59	5.80	

Note. All values are expressed as ml/kg/min.

Chapter 5

DISCUSSION OF RESULTS

Exercise is an important factor in the determination of caloric expenditure and the regulation of body weight. Dynamic exercise helps maintain fat free tissue and reduce body fat (American College of Sports Medicine, 1983). In conjunction with weight control, training also results in metabolic adaptations in the body. Therefore, exercise may have an effect on basal metabolism. Exhaustive exercise may elevate metabolic rate for up to 12-24 hours after exertion, thereby increasing caloric expenditure (Lamb, 1984). This investigation studied the effect of an 8-week exercise training program on basal metabolic rate (BMR). The results of this investigation will be discussed in this chapter.

The null hypothesis of this study was rejected because BMR decreased significantly ($p < .05$). These findings are supported by Cureton's (1969) results in which a decrease in BMR was seen following 8 weeks of strenuous training. Furthermore, Schneider and Foster (1931) also found a decrease in BMR in seven of nine athletes who trained for their sport for the duration of the season. However, because a significant training effect was not seen, it can not be concluded that training was certainly underlying the change in BMR seen in the present study.

It is difficult to explain why no training effect was observed following an 8-week training program. One possible explanation might be that the pretraining determination of VO_2max was prematurely terminated, leading to an exercise prescription that did not provide an adequate stimulus for training adaptations to occur. Factors such as leg fatigue, difficulty in breathing into the apparatus, and cramps caused most subjects to terminate the GXT before reaching their true VO_2max. Therefore, the training workload may not have been of sufficient intensity to elicit a training effect.

A second possible explanation for a lack of training effect may be poor adherence to the 8-week training program. Jobs, vacations, and time limitations occasionally interfered with training. These interferences may have precluded a training effect. Despite these problems, a change in BMR was observed in nine of the subjects, including four subjects who did not show an increased VO_2max following this 8-week period. Exercise training may have played a role in BMR fluctuations, however several alternative explanations for the significant changes seen in BMR can be presented.

Factors other than training may have contributed to the decrease in BMR. Two control subjects, who did not participate in an 8-week training program, were also studied. Their BMR decreased in a fashion similar to the 10 subjects that participated in the study. Therefore, factors other than exercise training were responsible for this decrease in BMR observed. Seasonal and hormonal changes are known to influence BMR and may account for the changes observed over the 8-week period.

Seasonal changes are known to affect the day-to-day metabolism of individuals. Benedict (1915) showed that BMR increased during the summer even though measurements were obtained under controlled laboratory conditions. Results in the current study tend to support Benedict's findings. Since data collection extended from the end of winter to the beginning of spring, the decrease in BMR after training may be related to the change in weather. Conversely, Pittman et al. (1943) showed that lower BMR values were seen during the winter and higher values in the spring and summer. Literature is not conclusive as to the true effect of seasonal variations on BMR, but it merits consideration as a factor influencing the results of this study.

In addition to seasonal changes, hormonal changes associated with the menstrual cycle are known to produce BMR fluctuations. Dubois (1930) confirmed through studies that metabolism increases during menstruation and decreases during premenstrual and intermenstrual days. Snell et al. (1920) also found a constant rise in BMR during menstruation and during the premenstrual period, while a decline was seen during the postmenstrual period. In the present study no data were kept on the subjects' menstrual cycles, however it is unlikely that all subjects were at points in their cycles at the time of BMR measurements that were similar enough to cause the consistent response seen in BMR. As a result, it is difficult to attribute the BMR changes observed in this study to hormonal variations.

Summary

The results of this study showed that BMR decreased coincidentally with the completion of an 8-week training program. Exercise training could possibly be involved in this change, however three subjects who showed decreased BMR did not experience a training effect as determined by changes in VO_2max. Additionally, a statistically significant training effect upon VO_2max was not found. Of the alternative explanations offered, seasonal changes are a viable factor that could possibly account for the obtained results. Since the study extended over two seasons, the significant change in environmental temperatures may contribute to the altered BMR measured.

Menstrual cycle changes have been shown to affect BMR, but it would be difficult to offer this as a major influencing factor. The likelihood of all subjects having similar cycle schedules is slim, therefore to attribute alterations in BMR to hormonal changes is not reasonable. As a result of this study, it seems exercise training and environmental changes are potential factors that affect BMR, and further investigation is needed to elucidate the roles of these factors.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was undertaken to determine the effect of an 8-week exercise training program on basal metabolic rate (BMR). The subjects (N = 12) were female Ithaca College students and faculty members between 19 and 30 years of age. Two of the subjects were controls and did not participate in the 8-week training program.

Each subject was tested by indirect calorimetry prior to training to determine her BMR. A graded exercise test (GXT) was also performed by each subject prior to training to determine her VO_2max. These results were used to develop an individual training program for each subject. Subjects trained a minimum of 3 times a week for 8 weeks on a bicycle ergometer. Posttraining measurements were acquired in a manner similar to pretraining tests. The pre- and posttraining data were tested for significant differences using a repeated measures t test. The mean VO_2max increase seen as a result of training was 1.59 ml/kg/min. The result of a repeated t test on these values was 0.58, not a signficant value.

Mean basal metabolic rates were found to be significantly lower after training than before training ($p < .05$). It was determined that training may have an effect on BMR.

However, this interpretation was inconclusive, because a significant training effect was not recorded and two control subjects, who did not participate in the training program, also experienced a decrease in BMR.

Conclusions

The results of this study yielded the following conclusion regarding the relationship between exercise training and BMR:

BMR decreased after 8 weeks of exercise training, but because training programs were not shown to be effective in increasing VO_2max, factors other than exercise should be considered as potentially more important to the changes in 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 during one season.

2. A study similar to the present one should be conducted that accounts for menstrual cycle changes or uses male subjects.

3. A study should be conducted that controls and monitors the training progress by arranging supervised training schedules for each subject.

Appendix A

DATA INFORMATION FORM

NAME ____________________ AGE ______ SEX ______ DATE ______

CHECK IF YES

PAST HISTORY

(In the past have you ever had?)

Rheumatic Fever	( )
Heart Murmur	( )
High Blood Pressure	( )
Heart Trouble:	
Rhythm Abnormalities	( )
Disease of Arteries	( )
Varicose Veins	( )
Lung Disease	( )
Injuries to back, knees, ankles	( )
Epilepsy	( )
Diabetes	( )
Stroke/Heart Attack	( )
How long ago? __________	
Operations?	( )
What kind? __________	
Other	( )

If other is checked, explain here: ____________________

FAMILY HISTORY

Have any blood relatives had? (parents, sister, etc.)

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

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	( )
Use more than one pillow to sleep	( )
Awaken short of Breath	( )
Loss of Consciousness	( )

Appendix A (continued)

RISK FACTORS

1. Smoking--Do you smoke? yes ( ) no ( ) Quit ( )
   Cigarettes ( )
   Cigars ( )
   Pipe ( )

   If quit, how many did you used to smoke a day? ____________

   How long have you been smoking? ____________
   How many do you smoke a day? ____________

2. Have you gained ( ) or lost ( ) weight in the last 2 months? Yes__ No__ How much?______

3. Do you presently engage in physical activity? (For example: bowling, tennis, gardening) Yes___ No___
   What kind? ____________
   How often? ____________

4. How far do you walk each day?
   Approximately-- 1-2 miles a day______
   3-4 miles a day______
   more ______

5. Is your occupation--Sedentary ( ), Inactive ( ), Active ( ) Heavy Work ( )
   Explain your occupation ____________

6. Do you have discomfort, shortness of breath, or pain with exercise? Yes___ No___
   If yes, what type of exercise: ____________

7. Are you taking any medications: Yes___ No___
   If yes, name the medications:

   ____
   ____
   ____

Appendix B

INFORMED CONSENT FORM

1. a) Purpose of the Study. The purpose of this study is to evaluate the effects of exercise training on basal metabolic rate (BMR).

b) Benefits. Improved cardiovascular function from 8 weeks aerobic exercise training. The subjects will feel better physically and may acquire an enhanced sense of well-being. An added benefit is a free evaluation (which usually costs approximately $125) of work capacity and cardiovascular function pre- and postexercise therapy.

2. Method. Subjects will make two trips to the Ithaca College Physiology Laboratory pre- and posttraining to calculate BMR. For each of these trips, subjects will arrive in the post absorptive state. BMR will be determined in the reclining position, in a dimly lit room. Subjects will train 3 days a week for 8 weeks on a bicycle ergometer. Workload will be initially prescribed according to graded exercise testing evaluation and be progressively increased during the 8-week period. Training sessions will be monitored by trained personnel. Training times and dates will be arranged according to mutual convenience of subject and tester.

3. Will this hurt? Some muscle soreness and fatigue may occur early in the training period as a result of the experiment, but no lasting physical or psychological pain is expected to result from this study.

4. Need more information? Additional information may be obtained from Pam Evans (273-8710) or Dr. Gary Sforzo (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 the data be maintained in confidence? Only the above named researchers will have access to these data. Complete anonymity will be maintained, and once data are collected, names will be replaced by coded numbers. In other words, all future data analysis will involve coded data, not individual names.

7. I have read the above, I understand its contents, and I agree to participate in the study. I acknowledge that I am 18 years of age or older.

______________________________ Signature ______________________________ Date

Appendix C

TRAINING SCHEDULE

Week	VO_2max (%)	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

Note. All workouts included a period of warm-up for 5-10 minutes prior to the workout.

Appendix D

BICYCLE ERGOMETER PROTOCOL

Time (min)	Resistance (kpm)	VO_2 (l/min)
2	150	0.60
4	300	0.91
6	450	1.21
8	600	1.51
10	750	1.81
12	900	2.11
14	1050	2.41
16	1200	2.74
18	1350	3.02

Appendix E

COMPUTER PRINTOUT OF METABOLIC DATA

SUBJECT 6
BODY WT-72.2 KG
HUMIDITY-45%

DATA REPORTS EVERY 30 SECS
AMB. TEMP.-24 C
BARO. PRES.-739 MMHG

TIME	VOLUME	VO2	ML/KG	CO2	RER	HR	RR
.5	4.65	.21	2.9	.16	.76	2	6
1	5.33	.26	3.6	.2	.76	0	8
1.5	4.57	.23	3.18	.17	.73	0	8
2	4.98	.25	3.46	.18	.71	0	6
2.5	5.25	.26	3.6	.19	.73	0	10
3	5.19	.25	3.46	.19	.76	0	10
3.5	5.73	.27	3.73	.2	.74	0	8
4	5.05	.24	3.32	.18	.75	0	12
4.5	6.21	.29	4.01	.22	.75	0	10
5	5.25	.24	3.32	.18	.75	0	8
5.5	4.98	.24	3.32	.18	.75	0	10
6	5.12	.25	3.46	.19	.76	0	10

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