5-2001

A Comparison of the Effects of Interval Training vs. Continuous Training on Weight Loss and Body Composition in Obese Pre-Menopausal Women.

Jeffrey Warren King
East Tennessee State University

A Comparison of the Effects of Interval Training vs. Continuous Training on Weight Loss and
Body Composition in Obese Pre-Menopausal Women

_____

A thesis

presented to

the faculty of the Department of Physical Education, Exercise, and Sports Sciences

East Tennessee State University

In partial fulfillment

of the requirements for the degree

of Masters of Arts in Physical Education

_____

by

Jeffrey W. King

May 2001

_____

Dr. Lynn Panton, Chair

Dr. Craig Broeder

Dr. Kathy Browder

Keywords: Obesity, Body composition, Resting metabolic rate, Interval training,

High intensity exercise

ABSTRACT

A Comparison of the Effects of Interval Training vs. Continuous Training on Weight Loss and
Body Composition in Obese Pre-Menopausal Women

by

Jeffrey W. King

The purpose of this study was to investigate the role exercise intensity plays in reducing body weight and percent body fat in overweight women. Subjects were randomized to either a high intensity interval training group (IT) or a lower intensity steady state training group (ST). Each group exercised 3 times per week for 8 weeks and expended 300 kcal per exercise session. VO_2max, body composition, and resting metabolic rate (RMR) were measured pre and post training. RMR was measured after exercise at week 2 to see if intensity levels affected RMR. VO_2max and body composition improved in IT but not in ST. Neither group showed a change in RMR from pretest to posttest; however, IT had an increase in RMR 24 hours post-exercise whereas ST did not. These findings show that high intensity interval exercise produces improvements in body composition, fitness, and acute RMR compared to low intensity steady state training.

ACKNOWLEDGEMENTS

CONTENTS

4

5

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In today's health-conscious society, there is a growing awareness of obesity in the United States. For various reasons, many people are becoming not just overweight, but over-fat as well. For reasons of appearance, health, or both, many overweight people undertake some form of diet or exercise program. At almost every grocery store check-out-stand, women's magazines describe new fad diets each month. Weight-loss drinks are popular and may aid in weight loss, but most people prefer to eat actual food than a milkshake every day. More and more health clubs are sprouting up all around the country to help people get in shape and lose weight. Health clubs aid in losing weight, but the same person who desperately strives to sell memberships is likely to do very little to encourage new members to return. Therefore, adherence to exercise, which is important in weight loss programs, becomes a major issue.

Changes in diet and/or exercise patterns are the primary ways for one to lose weight. A change in diet facilitates weight loss by restricting total caloric as well as fat intake. A change in exercise patterns also facilitates weight loss by increasing caloric and fat expenditure (Keim, Barbieri, Van Loan, & Anderson, 1990). Even though individuals may attempt to lose weight, many never meet their goals. Weight loss programs often lack the two major elements needed for long-term adherence—enjoyment and results. Someone may diet and exercise for a brief time, however, a lack of change in either appearance or weight (Grediagin, Cody, Rupp, Benardot, & Shern, 1995) and a lack of time or interest (Willis & Campbell, 1992) may prevent adherence to the weight loss program.

The problem of obesity is not unique to one segment of the population. Both men and women begin diet and exercise programs in an attempt to lose weight and body fat. However, women tend to have greater problems losing weight than men (Gleim, 1993). Women generally have smaller body sizes (Gleim), less fat free mass (Pollock et al., 1998; Westerterp, 1998), and lower resting metabolic rates (RMR) (Westerterp) than men. Men have greater testosterone levels than women, which causes them to have a greater muscle mass and absolute RMR than women (McArdle, Katch, & Katch, 1996). All of these factors cause women's energy expenditures for a given activity to be less than that of men. For this reason, it is important to find an exercise and/or diet program for women that will produce the results necessary for the participants to adhere to that program.

Traditionally, low intensity exercise was considered to be more beneficial than high intensity exercise because a greater percentage of fat calories are burned during low intensity exercise (McArdle et al., 1996). However, this line of thinking failed to consider the fact that a person's total energy expenditure per unit time is also very low; and consequently, the theromogenic effects during and following exercise are minimal. In contrast, while high intensity exercise requires a greater percentage of calories (kcal) from carbohydrate sources, the amount of total and/or fat calories used during and after exercise is often greater than that of lower intensity exercise. More importantly, following exercise, fat metabolism and RMR can be elevated for up to 24 hours (Bielinski, Schultz, & Jéquier, 1985; Treuth, Hunter, & Williams, 1996). This acute increase in fat metabolism and RMR will serve to aid in the facilitation of weight loss (via increased total daily energy expenditure (TDEE)) and in the metabolism of fat as opposed to carbohydrates. Currently, one of the more highly debated exercise methods is that of interval training as a possible treatment intervention for promoting a lean body. The participant

intermittently exercises at a high intensity alternating with a lower intensity every few minutes. Conversely, in continuous steady state training the participant exercises at the same intensity throughout the duration of the protocol. Even if an equal number of calories is expended during a high intensity interval training program as in a more moderate intensity steady state training program, substrate utilization during exercise will differ between the two programs. A higher intensity program would use primarily glycogen during exercise whereas a more moderate intensity program would use primarily fat. It is not uncommon for an individual to interpret this information as an argument that low to moderate intensity exercise is better for burning fat. However, this does not consider the fact that fat metabolism is increased after exercise, not just serving as the body's fuel source for any post-exercise activity, but also to replenish the glycogen stores depleted by the high intensity exercise. Many individuals are unable to maintain an extremely high intensity for an extended period of time, therefore necessitating that near maximal exercise be completed in an interval training program rather than a continuous steady state program.

Even though previous studies exist concerning the effect of interval training on performance, interval training has not been used as a possible means of weight loss, particularly in overweight women. Those studies that used overweight women as subjects used steady state training protocols for both the high intensity and low intensity training groups and found no significant differences between groups of overweight women when comparing body composition changes with high intensity and low intensity training. Grediagin et al. (1995) used overweight women and found no significant differences in weight, fat-free mass, and body fat percentage between a high-intensity training group (~80% of VO_2max) and a low-intensity training group (~50% of VO_2max) when caloric expenditure due to exercise was held constant. As Grediagin et

al. used a steady state program only, it remains unclear whether an interval training program that utilizes a greater intensity would cause decreases in weight and body fat percentage. If an interval training program is shown to produce changes in body weight and body composition, perhaps that type of program would be more appealing to those who have difficulty adhering to longer continuous steady state exercise programs.

Statement of the Problem

The purpose of this study was to compare the effects of high intensity interval versus low intensity steady state training on weight loss and body composition in obese pre-menopausal women. There is a lack of studies dealing with high intensity interval training programs as a potential means of weight loss. This indicates that such research must be conducted to determine if high intensity interval training is a viable means to reduce total body weight and fat mass.

Several sub-problems existed in determining the effect of high intensity interval training on weight loss and body composition. One sub-problem was the effect of the training method, either interval or steady state, on lean body mass. An increase in lean body mass could result in little or no change in weight, even if it coincided with a decrease in fat mass. An increase in lean body mass would accompany an increase in RMR, which could lead to a long-term change in body composition. Of greater importance than the effect on lean body mass was the possible effect of the training method on resting energy expenditure. An increase in RMR, and therefore TDEE, would facilitate weight loss while an individual is not exercising.

The primary dependent variables that were measured in this study were body weight and percent body fat. From these two variables, lean body mass was derived. Resting metabolic rate

was measured, as any change in RMR is crucial in the explanation of any differences in weight loss and body composition. Maximal oxygen uptake (VO_2max) was also measured in order to determine the appropriate training intensity for each subject. As previously noted, the primary independent variable in this study was the modality of training: interval training or steady state training.

Significance of Study

Obesity is a growing problem in the United States and currently affects over 50% of the adult population to some degree (National Institutes of Health [NIH], 1998b). Many people consider obesity to be a cosmetic problem. However, obesity increases a person's risk of significant health problems, the most important of which is coronary artery disease (American College of Sports Medicine, 1995). Every year, the health costs of obesity-related diseases approach $100 billion (NIH, 1998b). Effective weight loss programs for obese women nearing menopause have been difficult to find. After several months of exercise without any noticeable results, many people lose their motivation to continue exercise. In order to increase adherence to exercise, it is necessary to find a safe and efficient mode of exercise that allows the participant to see steady and significant results. Although improved cardiovascular fitness far outweighs physical appearance from a health standpoint, appearance is a far more tangible measure for the general population. Even though some participants are motivated by noticeable improvements in cardiovascular fitness, many will be deterred from exercising if they do not see a change in their body appearance with an exercise program designed to promote weight loss. Therefore, it is important to find a weight loss method that produces visible results. This study was intended to find a method of training, either aerobic or anaerobic, that will aid in the facilitation of body

12

weight loss and fat loss. The loss of weight and fat will increase the likelihood of participant adherence to a weight loss program.

Research Hypotheses

Even if caloric expenditure during exercise is held constant between a high intensity interval training program and a low intensity steady state training program, a higher intensity program can increase fat metabolism and RMR for 24 hours after exercise to a greater extent compared to a lower intensity program (Bielinski, et al., 1985; Treuth et al., 1996). Approximately 60-75% of TDEE comes from RMR (Wilmore & Costill, 1994); therefore, a significant increase in RMR will increase TDEE substantially. In turn, an increase in TDEE will facilitate weight loss. Higher intensity exercise may also produce post-exercise increase in fat metabolism, which will facilitate fat loss throughout the day at a greater rate than low intensity exercise (Broeder et al., 1991). The high intensity interval training program may have a greater likelihood of causing an acute increase in RMR than a low intensity steady state program. As such, this study had three hypotheses: 1) high intensity interval training will produce a greater increase in RMR 24 hours following an exercise session than low intensity steady state training; 2) high intensity interval training will produce greater loss of total body weight than low intensity steady state training; and 3) high intensity interval training will produce a greater loss of fat mass than low intensity steady state training.

Delimitations

Subjects in the present study were limited to 18 to 45 year-old female non-smokers with a body fat percentage Δ 30%. It was confirmed that older subjects had not yet reached menopause.

Individuals with cardiac conditions such as hypertension or uncontrolled diabetes or other conditions that would be contraindicated for exercise testing and training were not admitted to the study. Any individual who was taking medications that would alter metabolism was not admitted into the study. Each subject kept a daily food intake record that was used to determine if dietary changes occurred that might enhance or counteract the effect of the treatment.

The subject sample was comprised of volunteers from the surrounding community. The initial sample consisted of 32 subjects, 17 of whom dropped out of the study due to various reasons. Of the remaining 15 subjects, 7 subjects were assigned to an interval training group and 8 were assigned to a steady state group. A power analysis that was run based on the specifications of Glantz (1992) determined that 15 subjects would be appropriate for the present study.

Body composition was measured using dual energy x-ray absorptiometry (DEXA). Maximal aerobic capacity was measured using a graded exercise treadmill test. The results of the VO_2max test were used to determine the level at which a subject needed to exercise for a given exercise intensity. Resting metabolic rate was measured in the morning following a 30-minute rest period and under optimal resting conditions.

Assumptions

The following assumptions were made in this study:

1. With the exception of the research treatment, subjects neither increased nor decreased their daily activity from levels previous to the study.

2. Subjects neither increased nor decreased their daily caloric intake from levels previous to the study.

3.   An increase in RMR would lead to an increased in TDEE.

4.   An increase in TDEE that is greater than daily caloric intake would lead to weight

loss.

<div align="center">Limitations</div>

The following limiting factors of the study were recognized:

1.   The only way to determine if a subject was working exactly at a given percentage of

her VO_2max was through the use of indirect calorimetry. The use of a metabolic cart with every

exercise session was not be possible due to time constraints and subject consideration.

Therefore, exercise workload for each subject's prescribed VO_2 was determined using a linear

regression equation derived from her VO_2max test. VO_2 was then periodically checked with the

use of a metabolic cart.

2.   Many of the measurements have a degree of inter-rater variability. In order to avoid

differences caused by different raters, the same rater took the same measurements for both the

pretest and the posttest.

3.   Changes in estrogen levels during menstruation could effect RMR (Webb, 1986).

While hormonal levels were not be measured directly, no metabolic testing was done during a

subject's menstrual period.

<div align="center">Definition of Terms</div>

1.   Aerobic: exercising using oxygen (Wilmore & Costill, 1994)

2.   Anaerobic: exercising without the presence of oxygen; the work intensity is greater than the

rate the body can transport oxygen to be used (Wilmore & Costill, 1994)

3. Anaerobic threshold: the percentage of VO_2max at which metabolism goes from being aerobic to being anaerobic (Wilmore & Costill, 1994)

4. Body mass index (BMI): describes relative weight for height. Calculated as either weight (kg)/height squared (m^2) or as [weight (lbs)/height squared (in^2)] x 704.5. A BMI $\geq$ 25 is considered overweight and a BMI $\geq$ 30 is considered obese (National Institutes of Health, 1998a)

5. Calorie: unit of energy also known as the kilocalorie (kcal). 3500 kcal must be expended to burn one pound of fat (Wilmore & Costill, 1994)

6. Continuous training: steady-paced, prolonged exercise (McArdle et al. 1996)

7. Dual Energy X-ray Absorptiometry (DEXA): method of measuring body composition in which a filtered x-ray tube is used to distinguish between fat tissue, lean body mass, and bone mineral density (Lohman, 1996).

8. Interval training: mode of training that involves high-intensity of a very brief duration interspersed with brief periods of rest or low intensity exercise (McArdle et al., 1996)

9. Maximal oxygen uptake (VO_2max): used to measure cardiovascular fitness (ACSM, 1995)

10. Morphology: the form and structure of the body (Wilmore & Costill, 1994)

11. Obesity: unhealthy high body fat percentages, generally considered >20% for men and >30% for women (McArdle et al., 1996)

12. Resting metabolic rate (RMR): amount of energy required to sustain the body at rest. Accounts for approximately 60 to 75% of total daily energy expenditure (Wilmore & Costill, 1994)

13. Steady-state: the point in continuous exercise where workload and heart rate become constant (Wilmore & Costill, 1994)

14. Total Daily Energy Expenditure (TDEE): the amount of energy expended by the body in a

day. Total daily energy expenditure is influenced by RMR, the thermogenic effect of food,

and physical activity (McArdle et al., 1996).

CHAPTER 2

REVIEW OF LITERATURE

Researchers have attempted to determine the most suitable means of combating the growing problem of obesity in America. Most studies agree that exercise is an important component in any weight loss program. Even though studies may not find dramatic decreases in weight loss, they have found that exercise preserves lean mass and increases total daily energy expenditure (TDEE), which may facilitate weight loss over an extended period of time. However, the research does not agree on the most beneficial form of exercise. It has been found that continuous steady state exercise below lactate threshold for prolonged periods is as beneficial for weight loss or fat loss as higher intensity exercise (Grediagin et al., 1995). Conversely, interval training above lactate threshold for shorter periods of time has been found to be more beneficial for increasing TDEE (Treuth et al., 1996) which in turn yields greater caloric expenditure throughout the day. Even though high intensity continuous training as a means of weight loss has been studied (Grediagin et al.), there are limited data on the effects of high intensity interval training on weight loss or using a female population. Therefore, the purpose of the present study is to compare the effects of high intensity interval versus low intensity steady state training on weight loss and body composition in obese pre-menopausal women. The topics that will be covered in this chapter are (a) weight problems in women, (b) the effects of exercise on weight loss, (c) the effectiveness of exercise weight loss programs, including discussions on low to moderate intensity exercise and high intensity exercise, and (d) exercise and resting energy expenditure.

Weight Problems in Women

In recent years, obesity has become a growing international problem. The first plausible

cause for the obesity problem is that people are simply eating more. However, that is not the

only case. Some researchers have found that over the last several years, the occurrence of

obesity has increased while average energy intake has actually decreased (Hunter, Weinsier,

Bamman, & Larson, 1998). Although taking in fewer calories, many people are also expending

fewer calories. A decrease in TDEE combined with an increase in caloric intake has also been

cited as the cause for an increase in the prevalence of obesity (NIH, 1998b).

From the diverging trends in obesity and energy intake, Hunter et al. (1998) deduced that

a decrease in TDEE has accompanied the decrease in daily energy intake. Grediagin et al.

(1995) also acknowledged this trend. Heini and Weinsier (1997) found a 4% decrease in average

total calories consumed from 1977 to 1987 (1854 kcal to 1785 kcal). Heini and Weinsier found a

31% increase in the prevalence of overweight (defined as a body mass index $\geq$ 27.8 for men and

$\geq$ 27.3 for women) individuals over the same time period. Approximately 25.4% of the

American population were obese or overweight in 1977 as compared to 33.3% of the population

in 1987. These changes in diet and obesity were similar for both men and women. Although the

above researchers have concluded that inactivity rather than overeating is a major cause of

obesity in today's society, the NIH has found that this is not necessarily the case. The NIH has

determined there is an increase in dining out and portion size leading to an increase in caloric

intake in addition to the lack of activity (NIH, 1998b). This is in contradiction to a previous

report on a reduction of caloric intake by Heini and Weisner. According to the NIH (1998b),

both a rise in caloric intake and a decrease in TDEE have been found to be the primary causes of

the increase in obesity. Although the rise in moderate obesity does not necessarily coincide with

an increase in gross obesity, the increase in moderate obesity causes a greater societal problem than a few isolated instances of gross obesity (Shinkai et al., 1994).

Women are at a distinct disadvantage when compared to men when it comes to obesity. Women generally have smaller body sizes, and, as a result, their energy expenditures have been shown to be less than that of men performing the same activities (Gleim, 1993). For example, an 85-kg male running 10 kilometers in 45 minutes would expend 917 kcal (ACSM, 1995). A 55-kg female running the same distance in the same time would expend only 593 kcal (ACSM, 1995). The lower energy output is due to the woman's smaller body mass. Women are also at a disadvantage because they tend to have less fat-free mass than men. The average daily metabolic rates (ADMR) for women will therefore be less than that of men of the same ages and body sizes (Westerterp, 1998). The average basal metabolic rate (BMR) for men is considered to be 38 kcal/m^2/h while it is only 35 kcal/m^2/h for women (McArdle et al., 1996). Men have a higher BMR than women, therefore, they will in turn have a higher ADMR. The fact that women are in many cases smaller than men and that their ADMRs tend to be lower than that of men makes the weight loss process more difficult for women than for men.

The differences between men and women such as increased muscle mass and BMR are hormonally caused. Prior to puberty, men and women are physiologically similar; it is the presence of either testosterone or estrogen that leads to physiological changes. Increased testosterone leads to an increase in muscle mass whereas estrogen leads to an increase in fat deposits. With exercise, women increase their levels of testosterone, thereby increasing their muscle mass and BMR (McArdle et al., 1996).

The Effects of Exercise on Weight Loss

Traditionally, it was thought that low intensity exercise was more beneficial for fat loss than high intensity exercise. A greater percentage of fat calories is burned at a lower intensity and it was therefore thought that this equated to more fat loss (McArdle et al., 1996). However, this line of thinking failed to consider the fact that even though high intensity exercise might have a relatively lower percentage of fat calories expended, more total calories are expended during high intensity exercise for a given duration. This would increase the absolute number of fat calories expended during exercise of a given duration. In addition, low intensity exercise fails to increase the excess post-exercise oxygen consumption (EPOC) as greatly as high intensity exercise, especially high intensity exercise of longer durations. A greater EPOC leads to an increase in calories expended following the conclusion of the exercise bout (McArdle et al., 1996).

The most important aspect of how high intensity exercise causes weight and fat loss does not necessarily occur during the exercise itself. A higher exercise intensity can also cause an acute increase in RMR for up to 24 hours post-exercise (Bielinski et al., 1985; Treuth et al., 1996), which will increase caloric expenditure throughout the day. Additionally, even though high intensity exercise does not use as much relative fat as a fuel source during exercise, fat is burned to a greater extent following exercise in order to replenish the glycogen stores depleted during the high intensity exercise.

Some researchers have concluded that exercise without caloric restriction is not an effective means of absolute weight loss because exercise preserves or, in the case of resistance or high intensity cardiovascular exercise, increases fat-free mass (Keim et al., 1990; Kempen, Saris, & Westerterp, 1995). Researchers have also found that high intensity exercise facilitates fat

mass loss as well as preserving fat-free mass at a greater rate than low intensity exercise (Grediagin et al., 1995; Keim et al.; Racette, Schoeller, Kushner, Neil, & Herling-Iaffaldano, 1995; Tremblay, Simoneau, & Bouchard, 1994). This increase in fat-free mass serves to increase an individual's absolute RMR (Grediagin et al.), which, in turn, causes an increase in TDEE (Treuth et al., 1996) and, therefore, increases overall caloric expenditure.

It is necessary to find an exercise program that maximizes a woman's energy expenditure, thereby facilitating weight and fat loss. A major element in determining the type of exercise program that best facilitates weight loss is the program's effectiveness in increasing RMR, which will in turn increase TDEE (Hunter et al., 1998). A higher intensity program should cause a greater acute increase in RMR than a low intensity steady state program (Bielinski et al., 1985).

<u>The Effectiveness of Exercise Weight Loss Programs</u>

There exists a need to find a weight loss program that works effectively for women. Several studies have been conducted to determine the effectiveness of various exercise programs. Exercise programs of varying intensity and duration have been examined in order to determine which program is the most efficient for weight and fat loss. The following review will evaluate the effects of exercise and caloric restriction on weight loss and cardiovascular fitness.

<u>Low to Moderate Intensity Exercise</u>

Keim et al. (1990) divided 10 obese women (mean of $129 \pm 4\%$ of body weight desirable for height) into a group that underwent both exercise and caloric restriction (mean age 27 ± 3 years) and another that exercised only (mean age 25 ± 3 years). All subjects were admitted to

the metabolic suite in the research center for the duration of the study. Half of the subjects were placed on a diet necessary to maintain the subjects' weights without exercise and the other half were placed on a diet that allowed for only one-half of the caloric intake needed to maintain weight without exercise. Both groups exercised 6 days per week at 65-80% of the subject's VO_2max. The duration of the exercise program varied from subject to subject so that caloric expenditure due to exercise was constant. Exercise energy expenditure was set at 15% of the caloric intake necessary for each subject to maintain weight. There was a significant difference in weight loss ($p \leq 0.05$) between the diet/exercise group (13.08 ± 0.71 kg) and the exercise group (5.61 ± 0.62 kg). Using bioelectrical impedance it was found that 33% of the weight lost by the diet/exercise group was lean body mass whereas only 14% of the weight lost by the exercise group was lean body mass. This difference in lean body mass was not statistically significant, but it does indicate the tendency for exercise to preserve lean body mass.

Although Keim et al. (1990) exercised each treatment group so that all subjects would have the same caloric expenditure during exercise, causing duration to range from 31 minutes to 49 minutes, exercise intensity was not specifically set for either group. A wide intensity range of 65-80% of VO_2max gives no indication of the effects of exercise intensity on weight loss. Keim et al. also estimated VO_2max using a submaximal test rather than finding a true VO_2max. Keim et al. also estimated energy expenditure through heart rate, not indirect calorimetry. Even though Keim et al. found exercise to somewhat facilitate weight loss, the estimation of VO_2max and the wide intensity range provide little information regarding weight loss and exercise intensity.

Keim et al. (1990) are not alone in their findings that exercise in the presence of caloric restriction works to increase fat loss while preserving fat-free mass. Using a moderate exercise intensity (50-60% VO_2max) for 90 minutes per session three times per week for 8 weeks,

Kempen et al. (1995) found differences in substrate utilization for the diet group (D) when compared to the diet/exercise group (DX) ($p < 0.05$). Both groups were comprised of obese women (mean % body fat: D: $41.8 \pm 1.5\%$; DX: $41.6 \pm 1.5\%$) ages 25-50. The caloric restriction group was found to use 55% carbohydrates and 45% fats during exercise at the beginning of the study. At the end of the study, substrate utilization was found to be 60% carbohydrates and 40% fats. The change in substrate utilization from the beginning to the end of the study was not significant. The initial substrate utilization for the caloric restriction/moderate exercise group was 70% carbohydrates and 30% fats ($p < 0.05$). At the end of the study, substrate utilization changed significantly ($p < 0.05$) to 55% carbohydrates and 45% fats. This increase in fat utilization indicates the propensity for exercise to increase the overall expenditure of fat as energy, therefore promoting fat loss.

Racette et al. (1995) confirmed the previous findings that exercise prevented the loss of fat-free mass. Racette et al. assigned 30 obese (body fat $\geq 35\%$) pre-menopausal women (mean age 39 ± 5 years) to four groups: low fat diet/exercise (LFX), low fat diet/no exercise (LFNX), low carbohydrate diet/exercise (LCX), and low carbohydrate diet/no exercise (LCNX). The low fat diet consisted of 18% fat and 59% carbohydrates and the low carbohydrate diet consisted of 49% fat and 27% carbohydrates. Approximately one-fourth of all diets consisted of protein. The exercise protocol consisted of 45 minutes of exercise at 60-65% of VO_2max for 45 min/session three times per week for 12 weeks. The two groups that exercised had a trend to lose more weight (10.5 ± 3.3 kg) than the two groups that did not exercise (8.3 ± 2.6 kg; $p = 0.079$). Although this loss was not significant, Racette et al. noted the similarities between their findings and those of other researchers that also found that groups that exercised lost more weight than those that did not (Hill et al., 1989; Hammer, Barrier, Roundy, Bradford, & Fisher, 1989; Pavlou,

Steffe, & Lerman, 1985). However, more important than the difference in weight loss is the difference in fat loss, which was measured using isotope mass ratio spectrometry. In the exercise groups, 89.4% of the weight lost consisted of fat mass. This compares to only 71.3% fat loss in the groups that did not exercise. This difference in fat loss adds to the evidence that an exercise program is important in a weight loss program in that the addition of exercise to diet retains a higher percentage of fat-free mass.

Even though much of the research into weight loss consists of a caloric restriction component in addition to exercise, Grediagin et al. (1995) used high and low intensity exercise to examine weight loss changes. They used an initial sample of 18 moderately over-fat women ($31.1 \pm 3.8\%$ body fat and 30 ± 5 years old for the high intensity training group and $31.0 \pm 4.8\%$ body fat and 31 ± 6 years old for the low intensity training group) who were equally divided into either a low intensity (LI) training group ($\sim 50\%$ VO_2max) or a high intensity (HI) training group ($\sim 80\%$ VO_2max). Each group exercised on a treadmill four times a week for 12 weeks. The duration of each exercise bout was set at whatever level was necessary to elicit the expenditure of 300 kcal given a subject's weight and intensity level. Grediagin et al. found no significant between group differences for any of the changes in dependent variables: weight (HI: -0.7 ± 2.6 lbs; LI: -3.3 ± 2.6 lbs ; $\underline{p} = 0.115$), body mass index (HI: -0.1 ± 0.4; LI: -0.6 ± 0.5; $\underline{p} = 0.078$), percent body fat (HI: $-3.4 \pm 4.1\%$; LI: $-2.9 \pm 3.9\%$; $\underline{p} = 0.827$), sum of skinfolds (HI: -16.1 ± 7.0 mm; LI: -15.8 ± 6.5 mm; $\underline{p} = 0.947$), sum of circumferences (HI: -7.0 ± 4.5 cm; LI: -11.4 ± 6.8 cm; $\underline{p} = 0.223$), fat mass (HI: -5.0 ± 5.8 lbs; LI: -5.0 ± 5.8 lbs; $\underline{p} = .992$), fat-free mass (HI: $+4.3 \pm 5.4$ lbs; LI: $+1.8 \pm 5.0$ lbs; $\underline{p} = 0.417$), and VO_2max (HI: $+3.6 \pm 6.0$ ml$\bullet$kg$^{-1}\bullet$min^{-1}; LI: $+4.2 \pm 4.4$ ml$\bullet$kg$^{-1}\bullet$min^{-1}; $\underline{p} = 0.831$).

However, in one case Grediagin et al. (1995) found a significant pretest and posttest difference for the low intensity group where no significant change existed within the high intensity group. The low intensity training group lost a significant amount of weight (3.3 ± 2.6 lbs, $\underline{p} < 0.05$), whereas the high intensity training group lost only 0.7 ± 2.6 lbs. Since both groups lost an identical amount of fat mass (5.0 ± 5.8 lbs), measured using hydrostatic weighing and skinfold measurements, the between group difference in weight loss can be attributed to the fact that the high intensity training group increased fat-free mass more than the low intensity training group. The high intensity training group increased fat-free mass by 4.3 ± 5.4 lbs. The low intensity training group increased fat-free mass by 1.8 ± 5.0 lbs. Although neither figure is significant, the fact that this difference accounted for the significant decrease in body weight by the low intensity group could suggest a possible role of high intensity training in preserving fat-free mass, which will prevent a decrease in RMR.

Grediagin et al. (1995) found no difference between fat mass lost with high intensity training and fat mass lost with low intensity training and concluded that fat loss is the result of energy expenditure during exercise rather than intensity. However, the lack of any significant between group differences or significant intra-group differences could be accounted for by the small overall sample size ($\underline{N}$=12). The lack of significance of the between group differences could also be a result of the fact that the exercise protocols differed only in intensity and that the "high intensity" group exercised at approximately 80% of VO_2max rather than at or above the VO_2max. Both an increased exercise intensity and a larger sample size may have produced different results.

High Intensity Exercise

Even though cardiovascular exercise has been determined to advance the loss of fat mass, it still must be determined what type of cardiovascular exercise plays a greater role in fat loss: high intensity-short duration or low intensity-long duration. Tremblay et al. (1994) found that even though continuous endurance training led to a greater energy expenditure due to exercise than interval training, interval training led to a greater reduction in skinfolds. Tremblay et al. assigned their sample of 27 inactive subjects (13 male and 14 female, age 18 to 32 years) to two groups. Seventeen subjects were placed in an endurance training group (mean body weight 60.6 ± 13.4 kg) and ten subjects were placed in an interval training group (mean body weight 63.9 ± 11.0 kg). The protocol for the endurance training group lasted 20 weeks and the intensity began at 60% and increased to 85% of maximal heart rate reserve over the course of the study. The 15-week protocol for the interval training group consisted of three different programs. The greatest intensity at which subjects exercised was approximately 70% of the subject's 90-second maximal power output on the cycle. Short intervals ranged in duration from 15 to 30 seconds and longer intervals ranged in duration from 60 to 90 seconds.

Tremblay et al. (1994) found no decrease in weight for either the endurance training group (pre: 60.6 ± 13.4 kg; post: 60.1 ± 12.1 kg) or the interval training group (pre: 63.9 ± 11.0 kg; post: 63.8 ± 11.5 kg). The lack of a change in weight could be because none of the subjects were obese, therefore none had a large amount of weight to lose. The lack of weight loss could also be due to the fact that the subjects' diets were not controlled to prevent them from increasing their energy intake. Tremblay et al., however, found a significant difference in energy expenditure due to exercise between the two programs. The energy expenditure per session of the endurance training program was 120.4 ± 31.0 MJ whereas the energy expenditure per session

of the interval training program was 57.9 ± 14.4 MJ ($p < 0.01$). Even though energy expenditure was greater for the endurance training group, Tremblay et al. found that the interval training program resulted in a greater change in the mean sum of six skinfolds. The interval training group had a significant decrease in skinfold sums (94.2 ± 37.7 mm to 80.3 ± 36.0 mm; $p < 0.01$) whereas the endurance training group did not (79.2 ± 35.1 mm to 74.7 ± 34.2 mm; NS). Despite the significant decrease in skinfold sums for the interval training group, there was no between group difference in the degree of change for each group. However, once corrected for energy expenditure, the change in skinfold sum of the endurance training group was ~0.04 mm/MJ whereas the change for the interval training group was ~0.25 mm/MJ ($p<0.01$). The fact that the high intensity interval training group had a significantly greater change in the sum of six skinfolds indicated that higher intensity exercise may play a larger role in fat loss than exercise at a lower intensity and a longer duration.

As mentioned earlier, none of the subjects used in the study by Tremblay et al. (1994) were overweight, essentially negating the fact that no weight loss occurred. It remains unknown to what extent weight loss would have occurred had the subjects been obese. Also, the relative intensity of the endurance training exercise program gradually increased, so it is unknown what effect a program that remained at the same relative intensity would have had on energy expenditure.

Overend, Paterson, and Cunningham (1992) used interval training intensities over 100% VO_2max for the interval training groups in their study. Overend et al. assigned 29 (17 in the final data) active young males (mean height: 177.2 ± 7.4 cm; mean weight: 74.6 ± 8.6 kg; mean age: 25.1 ± 3.0 years) to three training groups. In order to establish an exercise base, the groups used identical exercise protocols for the first 2 weeks of the 10-week study. After 6 weeks, all

groups were retested in order to account for any changes in VO_2max. The exercise intensity

used in each of the three exercise protocols increased after 6 weeks. The continuous training

group (CT) exercised at approximately 80% of VO_2max. The low-power interval training group

(LT) exercised at approximately 100% of VO_2max. The high-power interval training group

(HT) exercised at approximately 120% of VO_2max.

The continuous training, low power interval training, and high power interval training

groups in the Overend et al. (1992) study had no significant differences in VO_2max among

groups (CT: 3.22 ± 0.55 to 3.47 ± 0.33 L•min; LT: 3.49 ± 0.26 to 3.82 ± 0.44 L•min; HT: $3.15 \pm$

0.22 to 3.67 ± 0.35 L•min). There was, however, a significant change in combined group mean

VO_2max (3.30 to 3.66 L•min, $p < 0.05$). More important to the present study, however, is the

significant decrease in the skinfold sums. The combined-group mean skinfold sums decreased

from a pretest level of 39.6 ± 11.3 mm to a posttest level of 36.5 ± 8.4 mm ($p < 0.05$). Although

there were no significant among group differences in skinfold sums, the significant decrease adds

to the evidence that both continuous and intermittent cardiovascular exercise facilitate fat loss.

As all subjects were active, it is unknown whether the use of obese subjects would have

produced weight loss to accompany the fat loss.

Gorostiaga, Walter, Foster, and Hickson (1991) found a significant change in the

VO_2max of the interval training group from the pretest to the posttest whereas a significant

change was not found in the continuous training group. Gorostiaga et al. assigned 12 subjects (3

males, 9 females; mean age: 27 ± 1.3 years) to a continuous training group ($\underline{n} = 6$) and an

interval training group ($\underline{n} = 6$). Both groups exercised on a cycle ergometer for 30 minutes a day,

3 days a week for 8 weeks. The continuous training (CT) group exercised at a constant workload

equivalent to approximately 50% of the subject's VO_2max. The interval training (IT) group

exercised at approximately 100% of VO_2max for 30 seconds and then rested for 30 seconds. After 8 weeks, no significant change was found in body mass (CT: 74.0 ± 9.5 kg to 74.3 ±9.6 kg; IT: 75.2 ± 6.0 kg to 72.5 ± 6.3 kg). No mention is made regarding body composition or weight/height relationship, so it cannot be determined whether lack of significant weight loss was due to the subjects being relatively lean. More importantly, a significant increase was found in the VO_2max of the interval training group (36.6 ± 1.1 ml•kg^{-1}•min^{-1} to 42.2 ± 1.7 ml•kg^{-1}•min^{-1}, $p < 0.05$). A slight increase in VO_2max was also found with the continuous training group (36.7 ± 1.6 ml•kg^{-1}•min^{-1} to 39.4 ± 1.4 ml•kg^{-1}•min^{-1}); however, this change was not significant. The fact that a significant change in VO_2max was found only with the interval training group (although the between group difference was not significant) indicates the potential for a difference in the physiological results stemming from interval training and those from continuous training.

Using young (mean age 23 ± 1 years) male subjects, Tabata et al. (1996) found significant increases in VO_2max for both continuous training and interval training groups. The continuous training group exercised on a cycle ergometer at approximately 70% of VO_2max for 60 minutes a day, 5 days a week for 6 weeks. The VO_2max of the continuous training group increased from 52.5 ml•kg^{-1}•min^{-1} to 57.5 ml•kg^{-1}•min^{-1} ($p < 0.01$). The interval training group performed seven to eight sets at approximately 170% of VO_2max until exhaustion 4 days per week. On the 5th day, the interval group exercised for 30 minutes at approximately 70% of VO_2max and then performed four exhaustive sets at approximately 170% VO_2max. The VO_2max of the interval training group increased from 48.0 ml•kg^{-1}•min^{-1} to 55.0 ± 6 ml•kg^{-1}•min^{-1} ($p < 0.01$). In addition to an increase in VO_2max, the interval training group also

exhibited a 28% increase in anaerobic capacity (the maximal possible intensity at which work can be performed). The mean anaerobic capacity of the interval training group increased from 60 ml•kg^{-1}•min^{-1} to 77.9 ml•kg^{-1}•min^{-1} ($p < 0.01$). Even with a higher exercise intensity for the continuous training group than that used by Gorostiaga et al. (1991), Tabata et al. concluded that high intensity interval training is a viable means of increasing VO_2max. Also, the significant increase in the anaerobic threshold indicated the increased capacity of the subjects to perform at a higher intensity. Performing at a greater intensity would, in turn, increase an individual's energy expenditure for a given exercise duration. However, it should be noted that the subject sample was comprised of active physical education majors who exceeded the average VO_2max for their age group (ACSM, 1995). The high intensity used with the interval training group may not be suitable for many subjects, especially overweight individuals.

Many researchers found that training produced significant changes in either the continuous training group or in the interval training group from pretest to posttest, but not between group differences in the change in the measured variable. Poole and Gaesser (1985) found between group differences in ventilatory threshold. Poole and Gaesser used three training groups in their study. All groups exercised on a cycle ergometer three times a week for 8 weeks. The first group exercised for 55 minutes at approximately 50% of VO_2max. The second group exercised for 35 minutes at approximately 70% of VO_2max. The third group performed 10 2-minute intervals at approximately 105% of VO_2max with a 2-minute rest between intervals. All groups experienced a significant increase in both lactate threshold (group 1: 1464 ± 93 ml/min to 2033 ± 135 ml/min; group 2: 1481 ± 46.2 ml/min to 2065 ± 53.4 ml/min; group 3: 1852 ± 49.4 ml/min to 2385 ± 55.4 ml/min; $p < 0.05$) and ventilatory threshold (group 1: 1191 ± 67 ml/min to 1415 ± 60 ml/min; group 2: 1418 ± 147 ml/min to 1822 ± 111 ml/min; group

3: 1528 ± 145 ml/min to 2227 ±155 ml/min; $p < 0.05$) from the baseline values. Not only were

all values significantly different than the baseline, but the post-training increase in ventilatory

threshold for the interval training group was significantly greater than the post-training increase

in ventilatory threshold of the other two groups ($p < 0.05$).

Poole and Gaesser (1985) found a significant among group difference in the change in

ventilatory threshold, which is evidence that high intensity interval training may produce

significantly different physiological changes than low or moderate intensity continuous training.

A significant among group difference in ventilatory threshold might not correspond directly to a

loss in weight or fat mass. However, an increase in ventilatory threshold will allow the subject

to work at a greater intensity, which would acutely increase RMR (Bielinski et al., 1985), which

increases TDEE, and therefore facilitates weight and fat loss (Keim et al., 1990; Racette et al.,

1995; Tremblay et al., 1994).

Sedlock, Fissinger, and Melby (1989) examined the effect of exercise intensity and

duration on magnitude and duration of EPOC. Ten trained male triathletes (mean age 26.0 ± 6.3

years) performed each of three exercise protocols: one of high intensity (75% VO_2max) and short

duration (HS), one of low intensity (50% VO_2max) short duration (LS), and one of low intensity

long duration (LL). The short duration exercise was sufficient to expend 300 kcal. The long

duration exercise was sufficient to expend 600 kcal. The HS, LS, and LL bouts lasted 19.9 ± 1.3

min, 29.6 ± 2.3 min, and 59.2 ± 4.5 min, respectively. Each training duration was significantly

different from the other two ($p \leq 0.05$). Following exercise, the duration and magnitude of

EPOC were measured. The duration of EPOC was considered the time from the end of exercise

to oxygen consumption returning to baseline values. The magnitude of EPOC was measured as

the caloric expenditure during this time period. The duration of EPOC for both HS and LL was

significantly greater than that of LS (HS: 33.3 ± 10.4 min, LL: 28.4 ± 14.1 min, LS: 19.8 ± 5.4 min; $p \leq 0.05$). However, although the duration of EPOC for LL was significantly greater than that of LS, no difference was found in the magnitude of the two low intensity groups (LL: 12.1 ± 6.6 kcal, LS: 14.3 ± 6.4 kcal) with the magnitude of HS (29.4 ± 8.4 kcal) being significantly greater than both LL and LS ($p \leq 0.05$). This finding indicates that exercise intensity effects both the magnitude and duration of EPOC whereas exercise duration only effects the duration of EPOC.

Broeder et al. (1991) also found that exercise intensity plays a greater role in the increase in EPOC than does exercise duration. Ten male subjects were equally divided into a lean group and a borderline obese group. All subjects participated in four exercise sessions. In two of these sessions, subjects walked at 30% of VO_2max and in two sessions, subjects walked on an incline at 60% of VO_2max. The duration of all exercise sessions was set to expend 720 kcal. In one session for each exercise intensity, subjects were given a post-exercise meal equal in caloric value to the energy expended. In the other two sessions, no replacement meal was given. Excess post-exercise oxygen consumption was then measured for three hours following the treatment period. In order to distinguish the effect of exercise on EPOC from that of dietary induced thermogenesis, only the non-feeding trials will be discussed. In both the lean and borderline obese groups, the exercise at 60% of VO_2max produced a significant change in oxygen uptake over this time (lean: 0.238 ± 0.02 L•min to 0.274 ± 0.03 L•min; borderline obese: 0.229 ± 0.01 L•min to 0.256 ± 0.02 L•min; $p \leq 0.01$). Despite the fact that the lower intensity exercise would have caused duration to be much longer than in the session at 60% of VO_2max, no such change was found in the session at 30% of VO_2max (lean: 0.239 ± 0.02 L•min to 0.252 ± 0.02 L•min; borderline obese: 0.235 ± 0.01 L•min to 0.248 ± 0.01 L•min; NS). This indicates that intensity

rather than duration or total energy expenditure during exercise will have an effect on EPOC for up to 3 hours post-exercise.

Maehlum, Grandmontagne, Newsholme, and Sejersted (1986) found that the increase in EPOC may extend to 24 hours post-exercise. Eight subjects (four male and four female) exercised in 10 to 30 minute increments for a total of 90 minutes of exercise at 70% of VO_2max. When compared to a control period, oxygen consumption had significantly increased for the 12 hours following exercise (E: 211 ± 16 L/12 h; C: 185 ± 13 L/12h; $p < 0.001$). This increase in the 12 hours immediately post-exercise led to a significant increase in 24-hour oxygen consumption as well ($p < 0.05$). While this study makes no mention of energy expenditure, the increase in EPOC over a 24-hour period indicates the possibility for an increase in RMR over this time period

Exercise and Resting Energy Expenditure

Perhaps more important than the immediate effect of a high intensity exercise program is the effect that a high intensity exercise program has on resting energy expenditure. Through previous studies conducted on young adult males, it appears that either a high exercise intensity or a long exercise duration are needed in order to cause an acute effect on RMR.

Poehlman et al. (1989) tested the acute effect of exercise on resting metabolic rate using six young (mean age 28.5 ± 3.5 years), untrained men. Prior to testing, all subjects were provided a similar diet. Subjects exercised on a cycle for 90 minutes at ~50% of VO2max and RMR was measured both 24 and 48 hours post-exercise. No change was found in RMR following exercise (pre: 1.17 ± 0.12 kcal•min^{-1}; 24 h post: 1.16 ± 0.12 kcal•min^{-1}; 48 h post:

34

1.16 ± 0.11 kcal•min^{-1}; NS). This finding indicates that if exercise is to have an acute effect on RMR, then the exercise will need to be either of greater intensity or greater duration.

Bielinski et al. (1985) used a steady state program of long duration to determine the effect of the former on resting metabolic rate. Ten conditioned male subjects (mean age: 21.8 ± 0.3 years) participated in the experiment, which lasted a period of 48 hours with energy expenditure being measured at set points throughout the study. During the first day, subjects did very little physical activity and maintained a constant meal time and content. During the second day, subjects maintained the constant meal time and content from the first day, but they also completed a 3-hour treadmill exercise. The intensity of the exercise was approximately $51.9 \pm 1.2\%$ of the subjects' predicted VO$_2$max. Resting metabolic rate was found to increase from 1.37 ± 0.05 kcal/min during the control period to 1.44 ± 0.06 kcal/min the morning following exercise ($p < 0.05$), an increase of approximately 100 kcal/day. This increase in RMR indicates the mechanism of exercise to facilitate weight loss. However, Bielinski et al. used a 3-hour exercise protocol. An exercise program of such a long duration has little practical relevance due to the fact that few people would be willing to make such a time commitment. Therefore, it is necessary to find a program that can have results similar to those found by Bielinski et al., but only in a shorter exercise duration.

Broeder, Burrhus, Svanevik, and Wilmore (1992b) found that exercise intensity plays a role in creating an acute effect on RMR. As part of a larger study, Broeder et al. assigned 15 male subjects (age 18-35) of varying fitness levels to an group performing progressive endurance training 4 days per week for 12 weeks. The progression was set so that each subject was working at a minimum of 70% of VO$_2$max for 40 minutes at the end of week 4. By the end of week 8, each subject was exercising between 70% and 85% of VO$_2$max for 50 minutes. The

final 4 weeks of training also included fartlek intervals at Δ 90% of VO_2max for 2 to 5 minutes. Fourteen hours following an exercise bout during the second stage of training (70-85% for 50 minutes), Broeder et al. (1992b) found that RMR increased significantly (5.24 kJ/min to 5.49 kJ/min; $p \leq 0.05$). This finding indicates that exercise of a much more practical duration than that used in the Bielinski et al. (1985) study can have an acute effect on RMR.

Unlike the Bielinksi et al. (1985) and the Broeder et al. (1992b) stuies, Treuth et al. (1996) compared high and low intensity exercise and found a significant difference in resting energy expenditure between high intensity and low intensity training groups. In the study done by Treuth et al., subjects spent three separate 24-hour sessions in a calorimeter. Each group served as its own control as the group that exercised at a high intensity for the first two sessions exercised at a low intensity the third session while the group that exercised at a low intensity for the first two sessions exercised at a high intensity the third session. With the exception of the exercise protocol, the activities for each group were identical: reading, watching television, and sleeping. The low intensity training group exercised on a cycle ergometer for 60 minutes at approximately 50% of VO_2max. The high intensity group completed 15 bouts of 2-minute exercise at approximately 100% VO_2max with a 2-minute resting recovery between bouts. The high intensity training group had significantly greater energy expenditure than the low intensity training group at rest (HI: 4.18 ± 0.55 kJ/min; LI: 3.90 ± 0.52 kJ/min; $p < 0.05$), during total exercise time (HI: 20.95 ± 3.41 kJ/min; LI: 17.09 ± 2.31 kJ/min; $p < 0.001$), and over a 24-hour period (HI: 5.94 ± 0.58 kJ/min; LI: 5.48 ± 0.53 kJ/min; $p < 0.01$). Because of the significant difference in resting and total daily energy expenditure between the high intensity and low intensity training groups, Trueth et al. concluded that exercising at a higher intensity allows for

36

greater energy expenditure throughout the day. The increase in daily and resting energy expenditure in turn leads to an increased loss of fat mass if not total body mass.

Summary

Several studies exist dealing with the issue of exercise and weight loss. There also exist several studies dealing with the effects of continuous training vs. interval training on various physiological markers. However, those studies that deal with exercise and weight loss, even when interval training was used, used either a low or moderate exercise intensity (Grediagin et al., 1995; Keim et al., 1990; Kempen et al., 1995; Racette et al., 1995). It is possible that using an exercise training program that is close to (i.e. >90%) 100% of VO_2max may produce different findings than using a higher intensity of less than 90% of VO_2max. Even though between group differences were found in other important training markers, no studies using an intensity near or greater than 100% of VO_2max (Gorostiaga et al., 1991; Overend et al., 1992; Poole & Gaesser, 1985; Tabata et al., 1996; Tremblay et al., 1994; Treuth et al., 1996) found a correlation between high intensity interval training and weight loss. However, none of these studies used subjects that were obese or even moderately overweight. No studies currently exist that use an exercise intensity near VO_2max to train either obese subjects or subjects with a mean age greater than 30.

The purpose of this study was to determine if an interval training intensity near VO_2max would produce greater weight and fat loss in pre-menopausal obese subjects than a low intensity steady state training program. High intensity exercise was found to increase fat-free mass (Grediagin et al., 1995), which in turn influences resting metabolic rate (Broeder et al., 1992a; Broeder et al., 1992b). A single bout of high intensity exercise was also found to increase EPOC

37

(Broeder et al., 1991; Sedlock et al., 1989) as well as total daily energy expenditure over a 24-hour period more so than lower intensity exercise (Broeder et al., 1992b; Treuth et al., 1996).

The conclusion can be made that exercise will facilitate fat loss. Since exercise assists in the loss of fat mass, it can be concluded that exercise even without caloric restriction will promote weight loss to some extent, but will promote fat mass loss to an even greater extent. Perhaps more importantly, the majority of the weight loss will be fat mass rather than fat-free mass. There is also a possibility of exercise increasing fat-free mass, which will preserve or even increase RMR during weight loss (Broeder et al., 1992a; Broeder et al. 1992b). A change in RMR, whether it is chronic due to an increase in fat-free mass or acute due to a high intensity exercise bout, will increase TDEE (Bielinski et al., 1985; Broeder et al., 1992a; Broeder et al. 1992b; Treuth et al., 1996), which will promote weight loss. In addition to an increase in TDEE, high intensity exercise will also work to increase fat metabolism at rest because of the necessary breakdown of fats in order to replenish glycogen stores (Coggan & Williams, 1995).

CHAPTER 3

RESEARCH METHODOLOGY

The purpose of this study was to compare the effects of high intensity interval versus low intensity steady state training on weight loss and body composition in obese pre-menopausal women. This chapter will discuss the (a) subjects, (b) instrumentation, (c) research protocol, and (d) design and analyses that were used in comparing the effects of the two training methods.

Subjects

The primary criterion for subject selection was that all subjects were clinically obese pre-menopausal women. Obesity in women was defined as having a body fat percentage greater than or equal to 30% (McArdle, et al. 1996). To avoid possible maturation due to the beginning of menopause, all subjects were between 18 and 40 years old; subjects ranging from 40 to 45 years of age were also allowed to participate if they had not reached menopause. The use of pre-menopausal women was to avoid any changes in RMR caused by lower estrogen levels. All subjects were weight stable, non-smokers, not pregnant, not lactating, and not taking any medications that could inhibit metabolism. Subjects did not have any medical conditions that were contraindicated to an exercise program or that could potentially hinder the effects of the exercise treatment.

No subjects were allowed to make a conscious change in eating habits. Because the purpose of the study was to determine the effects of high intensity interval and low intensity steady state training protocols on weight loss, any change in energy consumption would have had an effect on the data. Subjects were required to keep a 3-day food record on random,

consecutive days prior to beginning the treatment program and at the end of the treatment

program so that any changes could be noted.

Subject selection was voluntary and then limited only to those meeting the above criteria.

Based on the results of a power analysis (Glantz, 1992), the sample size was calculated to be 15-

20 subjects per group for a total of 30-40 subjects. Thirty-two subjects were recruited for the

study, with 17 subjects leaving the study for various reasons. The remaining 15 subjects were

randomly drawn into high intensity interval training and low intensity steady state training

groups.

Prior to the study, all subjects were asked to sign an informed consent form (Appendix A)

which was approved by the East Tennessee State University Institutional Review Board

(Appendix B). The informed consent notified subjects of all potential risks involved, including

the possibility of musculoskeletal injury and myocardial infarction. Subjects were also informed

that they would receive compensation for standard emergency care resulting from any injury

incurred as a result of the study. Subjects were told that they would be free to leave the study at

any time and that their personal records would be kept confidential.

<center>Instrumentation</center>

As this study dealt with the effect of high intensity interval and low intensity steady state

training protocols on weight and body composition, there were several measures taken. A

VO_2max test prior to the study was conducted in order to determine appropriate absolute

intensity levels for the subjects. The dependent variables, weight and body composition, were

measured at both the beginning and end of the study. Resting metabolic rate was also measured

<center>40</center>

at the beginning and the end of the study as well as a morning following an acute bout of exercise.

To maintain a consistent research protocol, a treadmill was used to test VO_2max. Each subject was tested for VO_2max using a Quinton Q55 Treadmill (Quinton Instruments; Seattle, WA), a Q4000 EKG montitor with a five-lead EKG (QI; Seattle, WA) and a SensorMedics 2900 metabolic cart (SensorMedics Corp.; Anaheim, CA). To measure VO_2max, the treadmill protocol designed by the ETSU Human Performance Laboratory for this study was used. Each subject began walking at 1.2 mph at a 0% grade for 2 minutes. During the second stage, speed increased to 3.5 mph with a 0% grade for 2 minutes. At this point, the speed remained constant and the grade increased by 1% for the following 2 stages and by 2% after that. With the exception of the first 2 stages, all stages were 1 minute in duration. The test was terminated when the subject went to volitional fatigue. VO_2max was defined as meeting at least two of the following three criteria: reaching age predicted maximum heart rate, a respiratory exchange ratio (RER) greater than 1.1, and a plateau in VO_2 between successive stages.

Body composition was measured through Dual Energy X-ray Absorptiometry (DEXA) using a Lunar™ QDR system according to the specifications of Lohman (1996). Transverse scans of the subject's whole body were made in the anteroposterior position. Scans were made in 0.6 to 1.0 cm intervals over the area being scanned. Standard error for this method of measuring body composition ranges from 2.5% to 3.5%. Body weight was measured on a Portotronic (Cape Coral, FL) scale accurate to 100 grams. Each body composition and weight measurement was made by a single rater throughout the study in order to control for inter-tester error.

Menstruation has been found to have an effect on RMR (Webb, 1986); therefore, the RMR test was scheduled around each subject's menstrual period. Resting metabolic rate was measured as described by Broeder et al. (1992a, 1992b). Prior to testing, all subjects had a restful night's sleep (equal to her normal volitional hours of sleep), did not eat or consume liquids other than water in the 12 hours preceding the test, and abstained from caffeine for 24 hours prior to the test. Subjects were asked not to perform exercise for at least 48 hours prior to the test. Subjects were transported by car to the testing center and rested in a semirecumbent position for 30 minutes prior to the test. An airtight SensorMedics (CA) ventilatory hood was positioned on the subject. Ventilation, VO_2, and respiratory exchange ratio (RER) were measured for 30 minutes. The subject remained inactive and the noise and light level in the room were diminished. Data were collected using a SensorMedics 2900 metabolic cart, which was calibrated with standard calibration gases at 26% O_2, 0% CO_2 and 16% O_2, 4% CO_2.

The RMR test took place in the morning after an overnight fast. VO_2max and DEXA tests took place in the afternoon following a minimum 4-hour fast. Subjects were given appropriate instructions concerning food intake and activity prior to all tests. The scheduling of testing was set so that no test was affected by the previous test.

Research Protocol

On completion of pretest period, subjects were randomized into either a high intensity interval training group or a low intensity steady state training group. Training consisted of a 5-minute warm-up period at ~30% of VO_2max for both groups. The high intensity interval training group alternated 2-minute intervals of 95% VO_2max with 3-minute intervals at a speed of 1.2 mph with a 0% grade, which equaled ~30% of each subject's VO_2max. The timings of the

intervals caused the interval training group to average ~55% of VO_2max over the entire duration of the exercise session. In the low intensity steady state group, after the 5-minute warm-up, the intensity was increased to 50% of VO_2max for the duration of the exercise. All subjects exercised three times a week for 8 weeks. Caloric expenditure during exercise was set at 300 kcal for both groups, creating the necessity of a variation in exercise times among individual subjects. Each person's metabolic workload was verified at the beginning of the study and again after 4 weeks using the SensorMedics metabolic cart system. Unless a lower speed was necessary due to lower fitness levels, speed was set at 3.5 mph and intensity was altered by increasing the grade as needed. At no point did the treadmill speed exceed 3.5 mph. Duration of exercise was determined by entering kcal/min data based on liters of O_2 and non-protein RER into a Microsoft Excel program at 20-second intervals. Exercise was halted when the sum total of the data equaled 300 kcal. Due to varying weight and fitness levels of subjects, duration of exercise ranged from 37 minutes to 65 minutes. The average duration for the high intensity interval training and the low intensity steady state training groups was 51.0 ± 9.1 min and 51.1 ± 8.9 min, respectively ($p = 0.97$; Table 1, Appendix C). Many of the subjects had very little or no prior experience walking on a treadmill and, in the interests of subject comfort, were allowed to rest their hands on the treadmill for balance. Those subjects who placed their hands on the treadmill were requested to do so for all tests and exercise sessions. Doing this in every session prevented discrepancies in session to session exercise intensity and caloric expenditure as determined by the metabolic assessment trial.

At the midpoint of the study, VO_2max was again measured in order to determine if the absolute intensity needed to be altered. At this time, each subject was also tested at her absolute intensity to determine if the new estimation of workload and duration were equal to the desired

43

relative intensity and duration. Treadmill speed and grade were adjusted as needed. Each subject also underwent a second RMR test that measured RMR following a day of exercise in order to determine acute effects of each respective training period on RMR. This acute RMR test was conducted within the first 2 weeks of training, on average ~17 hours after the end of the exercise session. Most subjects completed this test within two weeks, with two subjects completing it during the third week due to scheduling difficulties. At the end of the study, all measurements were repeated with the exception of the acute RMR test.

Design and Analyses

Since the subjects in this study were randomized into two experimental groups, this study was a pretest-posttest randomized-group design. Each of the two groups received the same pre and posttest. A student's t-test was used to determine if between group differences existed prior to testing. In order to control for any potential between group differences prior to testing, an ANOVA model was used to determine if significant between group differences were present. If there were significant differences, an ANCOVA model was used and adjusted means were presented. A repeated measures ANOVA was used to determine pre to post differences for the two groups. All significance was accepted at $\underline{p} \leq 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

With the growing rate of obesity in America, it is necessary to find a means to help reverse the trend towards weight gain. For this to be done successfully, energy balance must be manipulated so that more energy is expended than consumed. The only way that this can be a lasting change is for the method by which energy balance is altered to be a permanent lifestyle change. Many means of weight loss are designed to serve as a temporary solution and, therefore, once the program ceases and the individual returns to his or her previous lifestyle, the weight is regained.

The purpose of this study was to compare the effects of high intensity interval training and low intensity steady state training on resting energy expenditure, weight loss, and body composition on non-dieting pre-menopausal obese women. Previous research in this area has used submaximal protocols (~80% of VO_2max) for the higher intensity training and have found very little change in body composition (Grediagin et al., 1995). When using an intensity near or above VO_2max, changes were found in resting energy expenditure, but not body composition (Tremblay et al., 1994; Treuth et al., 1996). However, the reason that there were no changes in body composition could be due to the use of lean populations in these studies. The present study is the first to use a near or greater than pre-treatment maximal exercise intensity (~95% of VO_2max) with an obese population. The three research hypotheses of this study were 1) high intensity interval training would produce a greater increase in resting metabolic rate (RMR) 24 hours following an exercise session than low intensity steady state training; 2) high intensity interval training would produce a greater loss of total body weight than low intensity steady state

45

training; and 3) high intensity interval training would produce a greater loss of fat mass than low intensity steady state training. Resting metabolic rate comprises up to 75% of a person's total daily energy expenditure (TDEE) (Wilmore & Costill, 1994). As such, it is likely that an occurrence of the first hypothesis would lead to the occurrence of the next two hypotheses.

<div align="center">Subjects</div>

Thirty-two female subjects, ages 18 to 45, were randomly assigned to either a high intensity interval training group or a low intensity steady state training group. All subjects had a body fat percentage greater than or equal to 30%. Due to varying reasons, primarily either lack of time or change of interest, 17 subjects dropped out during either the testing period (n=11) or during the first week of training (n=6). Two more subjects, one from each group, dropped out at the midpoint of the training period due to lack of time. Of the 15 remaining subjects, 7 were randomized to the high intensity interval training group and 8 were randomized to the low intensity steady state training group. Fourteen subjects were Caucasian; one was African-American. Six subjects took part in exercise or sports programs prior to participation in the study and all remaining subjects had active jobs; therefore, although the subject population for this study was obese, it was not sedentary. Subject pre-treatment physical characteristics are presented in Table 2 (Appendix C). After performing a t-test on all dependent and independent variables, no significant pre-treatment differences in any of the physical, metabolic, or dietary characteristics were found between the two groups.

Maximal Oxygen Consumption

Although none of the original hypotheses dealt with maximal oxygen consumption, one finding of this study was that the high intensity interval training group experienced a significant increase in VO_2max whereas the low intensity steady state group had no change. A significant increase in VO_2max, determined by the meeting of two out of three criteria—plateau in VO_2, RER greater than 1.1, and/or age predicted maximum heart rate—was found in the high intensity interval training group (24.6 ± 4.1 ml•kg^{-1}•min^{-1} to 28.2 ± 4.7 ml•kg^{-1}•min^{-1}; $p < 0.01$; Fig. 1, Appendix D). No such change was found in the low intensity steady state training group (27.57 ± 3.976 ml•kg^{-1}•min^{-1} to 26.72 ± 4.189 ml•kg^{-1}•min^{-1}; NS; Fig. 1). These differences constitute a +14.8% change in VO_2max for the high intensity interval training group and no change in VO_2max for the low intensity steady state training group. This difference in change between groups was significant (p=0.001; Fig. 2, Appendix D).

The natural assumption in finding a change in relative VO_2max in addition to a change in body weight is that the change in weight, at least in part, caused the change in VO_2max. However, a 12.2% increase was found in the absolute VO_2max of the high intensity interval training group whereas no change occurred in the low intensity steady state group (IT: 2.25 ± 0.30 L•min to 2.52 ± 0.36 L•min; $p < 0.01$; ST: 2.48 ± 0.63 L•min to 2.44 ± 0.59 L•min; NS; Fig. 3, Appendix D).

The data in this study indicate that an exercise intensity of greater than 50% of VO_2max is needed to increase maximal oxygen consumption in obese pre-menopausal women. These findings are in conflict with other studies that also used an exercise intensity of 50% of VO_2max (Gorostiaga et al., 1991; Grediagin et al., 1995). Gorostiaga et al. found a 15% increase in VO_2max (36.3 ± 1.1 ml/kg/min to 42.2 ± 1.7 ml/kg/min; $p \leq 0.05$) with high intensity interval

training (100% VO_2max); however, they also found a 7% increase in VO_2max (36.7 ± 1.6 ml•kg^{-1}•min^{-1} to 39.4 ± 1.4 ml•kg^{-1}•min^{-1}; NS) with low intensity steady state training (50% VO_2max). Grediagin et al. (1995) found no significant change in VO_2max for either a high intensity group (80%) or a low intensity group (50%). However, the pattern found was similar to that found by Gorostiaga et al.. The 80% and the 50% intensity group sexhibited an 11.4% increase and a 13.4% increase in VO_2max, respectively.

While neither Gorostiaga et al. (1991) nor Grediagin et al. (1995) found a significant change in VO_2max for exercise training at 50% of VO_2max, both studies show a pattern in this variable not exhibited by the present study, which found essentially no change (3.1% decrease) in VO_2max with training at 50% of VO_2max. There are some possible explanations for this difference. Gorostiaga et al. used a mixed gender, non-overweight population with a mean age of 27 ± 1.3 years. Therefore, gender, weight, and age all could have been factors in the difference in findings. Grediagin et al. used a moderately overfat population; however, both studies used subjects who were sedentary. Three of the subjects in the present study played competitive amateur tennis several times a week. Three other subjects also took part in walking or jogging programs prior to participation in the study and, in order to prevent a change in activity other than the treatment from affecting data, were encouraged to continue their programs. All other subjects had jobs that required that they be active. The population in the present study led active lifestyles, even though many had not been exercising prior to the study. The fact that this was not a sedentary population could indicate that a workload of 50% of VO_2max is not a great enough intensity to improve VO2max in a non-sedentary, albeit untrained, population.

Weight/Body Composition

There were no significant changes in either group for body weight, body mass index (BMI), or anthropometric measurements of the waist and hip after the treatment period (Table 3, Appendix C). There were also no between group differences in the percent changes of these measurements. However, this was not the case regarding measures of body composition. Body fat percentage was measured using DEXA. Body fat percentage for the high intensity interval training group decreased from $45.5 \pm 7.8\%$ to $43.5 \pm 6.9\%$ ($p=0.07$). While this is not significant, it does show a trend towards significance that could possibly be found with a larger sample size, a longer treatment period, or an increase in training volume. Conversely, body fat percentage for the low intensity steady state group showed no change ($42.4 \pm 5.2\%$ to $42.9 \pm 4.6\%$; NS). Even though the change in body fat for each group was not significant compared to the pretest measure, the degree of change between groups was significant. The high intensity interval training group exhibited a -4.4% change in body fat whereas the low intensity steady state group exhibited a +1.2% change in body fat ($p < 0.05$; Fig. 4, Appendix D).

The reason for this change may be attributed to the significant decrease in fat weight found in the high intensity interval training group (44.1 ± 17.4 kg to 41.8 ± 17.3 kg; $p < 0.01$). No significant change was observed in the fat weight of the low intensity steady state training group (39.362 ± 14.145 kg to 40.117 ± 13.917 kg; NS). Furthermore, a comparison of the change between groups found a -5.3% change in fat weight of the high intensity interval training group whereas the low intensity steady state group had a +1.9% increase, creating a significant difference in percent change between groups ($p < 0.01$; Fig. 5, Appendix D). No significant differences were found in either the change in fat-free weight (IT: 49.9 ± 8.4 kg to 51.0 ± 9.9 kg,

49

NS; ST: 51.5 ± 8.8 kg to 51.5 ± 8.6, NS) or in percent change of fat-free weight between groups (IT: +2.2%, ST: - 0.1%, NS).

To determine if changes in body composition were the result of the treatment or a conscious dietary change on the part of the subjects, a 3-day dietary recall was given to the subjects before, mid-way through, and after the study. Only 11 of 15 subjects (6 IT, 5 ST) returned all dietary recalls. Of these subjects, no significant changes were found in the subjects' diets over the course of the study (Table 4, Appendix C).

Although the change in total body weight was not significant, fat weight decreased significantly in the high intensity interval training group. In contrast, no change was found in fat-free weight for the high intensity interval training group. This preservation of fat-free weight is possibly enough to lead to the lack of a significant change in total body weight. Broeder et al. (1992b), when training subjects for 12 weeks, found a significant decrease in body fat with endurance training (18.5 ± 1.9 to 17.0 ± 1.5%). Like the present study, Broeder et al. found no change in total body weight, but this was attributed to a preservation of fat-free weight and a decrease only in fat weight (14.6 ± 2.0 kg to 13.2 ± 1.7 kg).

In a study similar to the current study, Grediagin et al. (1995) found a significant decrease in the total body weight with interval training. Although such a change did not occur in the present study, Grediagin et al. used a 12-week training period with a frequency of four times per week, for a total of 48 sessions. The present study used an 8-week training period with a frequency of three times per week, for a total of 24 sessions, or one-half of the number used by Grediagin et al. It is possible, based on the directional body composition changes observed in this study, that a treatment duration and exercise frequency similar to that used by Grediagin et al. may have produced similar results.

50

Despite significant weight loss, Grediagin et al. (1995) did not find a significant change in body composition. Grediagin et al. concluded that because the two groups expended the same number of calories during exercise, that fat loss was a function of energy expenditure, not intensity. In a sense, this conclusion may have been correct. However, what was not taken into consideration is that a higher exercise intensity may lead to greater post exercise energy expenditure. For their high intensity training group, Grediagin et al. used an intensity of ~80%. However, studies in which a maximal or supramaximal exercise intensity was used found significant decreases in skinfold sums (Overend et al., 1992; Tremblay et al., 1994) even when the population used was athletic rather than overweight. Prior to the current study, no study had been completed in which an obese population exercised at a near maximal intensity. The significant difference in the percent change of body fat percentage indicates that the high intensity interval training group was able to burn fat at a greater rate than the low intensity steady state group, despite the fact that each group had the same caloric expenditure during exercise. Grediagin et al. concluded that fat loss was a function of energy expenditure, not exercise intensity; however it is likely that when exercise intensity is increased to near maximal levels, that post exercise energy expenditure will be greater than it would be with a lower intensity, therefore leading to greater fat loss.

Resting Metabolic Rate

There were no changes from pretest to posttest in RMR, resting VO_2, resting VO_2/kg total body weight, VO_2/kg fat free weight, or in resting respiratory exchange ratio (RER) (Table 5, Appendix C). However, changes were noted in most of these markers in the acute RMR test conducted within 24 hours of a bout of high intensity interval training. In the high intensity

51

interval training group, RMR increased 4.4% from 1688 ± 373 kcal/day in the pretest to $1762 \pm$ 376 when measured in the morning after subjects' training sessions ($\underline{p} = 0.05$). Such a change was not found for pre training RMR to post training RMR, both of which were tested a minimum of 48 hours after a previous bout of exercise. Significance was also found when measuring resting VO_2/kg of body weight (2.63 ± 0.34 ml$\bullet$kg$^{-1}\bullet$min^{-1} to 2.74 ± 0.33 ml$\bullet$kg$^{-1}\bullet$min^{-1}; $\underline{p} \leq$ 0.05). Although significance was not found, a trend existed in the change for both resting absolute VO_2 (243 ± 54 ml$\bullet$min^{-1} to 253 ± 53 ml$\bullet$min^{-1}; $\underline{p}=0.07$) and resting VO_2 adjusted for fat free weight (4.9 ± 0.6 ml$\bullet$kg^{-1}FFW$\bullet$min^{-1} to 5.1 ± 0.6 ml$\bullet$kg^{-1}FFW$\bullet$min^{-1}; $\underline{p}=0.06$). No changes were found in these markers for the steady state group, nor was a change found in RER for the acute RMR test in either group. There was also no significant difference between groups in the percent change of acute RMR data. It should be noted that this change occurred during the first few weeks of exercise. A possibility exists that the increase in RMR due to exercise seen initially may have disappeared as the 8 weeks progressed.

Other studies found a similar effect of exercise on acute RMR as did the present study (Table 6, Appendix C). Poehlman et al. (1989) exercised six untrained (mean VO_2max: $50.1 \pm$ 5.0 ml$\bullet$kg$^{-1}\bullet$min^{-1}), nonobese (mean body fat percentage: $12.9 \pm 3.9\%$) male subjects (mean age: 28.5 ± 3.5 years) on a cycle ergometer for 90 minutes at 50% of VO_2max. No change was found in resting metabolic rate either 24 or 48 hours post-exercise (pre: 1.17 ± 0.12 kcal/min; 24 h: 1.16 ± 0.12 kcal/min; 48 h: 1.16 ± 0.11 kcal/min; NS). Poehlman et al. concluded from this finding that exercise does not have an acute effect on RMR. However, like the present study, what the findings of Poehlman et al. indicate is that if exercise is to have an acute effect on RMR, an intensity greater than 50% may be needed.

52

Bielinski et al. (1985) determined that 50% of VO_2max could have an acute effect on RMR; however, they used an exercise duration of 3 hours. Ten athletic (mean VO_2max: 62.5 ± 2.2 ml•kg^{-1}•min^{-1}), lean (mean percent body fat: 11.9 ± 0.6%) male (mean age 21.8 ± 0.3) subjects took part in a single bout of low intensity, high duration exercise. Resting metabolic rate was tested 18 hours after exercise and a 4.7% increase was found over the pre-exercise test (pre: 1.37 ± 0.05 kcal/min; acute: 1.44 ± 0.06 kcal/min; $p < 0.05$). This finding indicates that a low exercise intensity can have an acute effect on RMR, provided a long duration is used. However, this data has little practical implication due to the long duration.

Broeder et al. (1992b) found that exercise has an acute effect on RMR when a high intensity but a more moderate duration is used. Fifteen males, age 18-35, of average body composition (mean body fat percentage: 17.0 ± 1.5%) and varying fitness levels (mean VO_2max: 55.2 ± 2.2 ml•kg^{-1}•min^{-1}) participated in 8 weeks of progressive endurance training prior to being tested for RMR. Resting metabolic rate was tested 14 hours following a 50-minute bout of exercise with intensity varying from 70 to 85% of VO_2max. Following exercise, an acute 4.8% increase was found in RMR (pre: 5.236 kJ/min; acute: 5.487 kJ/min; $p < 0.05$). Whereas Bielinski et al. (1985) demonstrated the acute effect of exercise duration on RMR, Broeder et al. demonstrated the effect of exercise intensity on RMR, a finding that is similar to that of the present study.

The present study, Bielinski et al. (1985), and Broeder et al. (1992b), respectively, found a 4.4%, a 4.7%, and 4.8% acute increase in RMR following a bout of exercise. What separates the present study from the other two is the population that was used. The present study used obese pre-menopausal women whereas the other two used lean, moderately trained males. The fact that the present study found a similar finding in a population so distinct from other studies

indicates that the effect of high intensity or long duration exercise on RMR my have no relation to body fat percentage or training status.

One of the design flaws of the present study was that the acute RMR test occurred within two weeks of subjects beginning the training protocol. There was some speculation as whether the acute increase in RMR following high intensity interval training would have been found at the end of the study. However, Broeder et al. (1992b) tested acute RMR after 8 weeks of training. Additionally, both Broeder et al. and Bielinski et al. (1985) used a population that had much more prior training that of the current study. In light of these facts, it appears that there likely would have been no difference in the data had the acute RMR test occurred at the end of the training period.

There is a possibility, however, that high intensity exercise may not act alone in having an acute effect on RMR. Bullough, Gillette, Harris, and Melby (1995) studied the interaction between diet and exercise on RMR by using four different diet/exercise combinations with a single group of subjects. The four combinations used were high energy flux (90 minutes of exercise at 75% of VO_2max with caloric replacement), low energy flux (no change in exercise or diet), negative energy balance (90 minutes of exercise at 75% of VO_2max without caloric replacement), and positive energy balance (no exercise, but caloric intake equal to that taken in during exercise). In light of the aforementioned studies, one would expect that if no interaction existed between diet and exercise in producing an acute increase in RMR, that RMR would increase in both high energy flux and negative energy balance. However, that was not the case. A significant increase was found in acute RMR in high energy flux, but acute RMR was the same in negative energy balance as it was in low energy flux and positive energy balance. This

finding indicates that not necessarily high intensity exercise alone, but high intensity exercise combined with caloric replacement to produce a high energy flux leads to an increase in RMR.

While a controlled program such as that used by Bullough et al. (1995) was not used by Broeder et al. (1992b) or Bielinski et al. (1985), both produced a high energy flux by replacing much of the calories expended during exercise. In the present study, subjects were allowed to eat ad libitum following exercise so it could not be determined whether the high intensity interval training group was in a state of high energy flux. However, when acute RMR was compared to self-reported energy intake prior to the study (Table 7, Appendix C; Fig. 6, Appendix D), the high intensity interval training group was in a state of neutral energy balance (pre kcal in: 1717 ± 520 kcal/day; acute RMR: 1705 ± 377 kcal/day; similar at $p < 0.05$) whereas the low intensity steady state training group was in a state of negative energy balance (pre kcal in: 1479 ± 513 kcal/day; acute RMR: 1957 ± 377 kcal/day; NS). It should be noted that one member of the high intensity interval training group and three members of the low intensity steady state training group did not return their pre-training dietary recalls. Although the negative energy balance of the low intensity steady state training group is not significant ($p = 0.14$), the low P-value and high standard deviation indicate that significance may have been found had all subjects completed the dietary recall. Although not officially controlled, this data indicate that the high intensity interval training group was in an energy flux great enough to lead to a change in RMR.

Research Hypotheses

The three research hypotheses for this study were 1) high intensity interval training would produce a greater increase in RMR 24 hours following an exercise session than low intensity steady state training; 2) high intensity interval training would produce a greater loss of

total body weight than low intensity steady state training; and 3) high intensity interval training would produce a greater loss of fat mass than low intensity steady state training. This study found a significant increase in RMR within 24 hours of a high intensity interval exercise session while no such increase was found in the steady state group. Therefore, the research hypothesis that high intensity exercise produces a greater increase in acute RMR is not rejected when evaluating the first two weeks of an exercise program. The fact that other studies (Bielinski et al., 1985; Broeder et al., 1992b) found a similar effect after training may indicate that a similar effect may also have occurred at the end of the training period. There was no significant change in total body weight for either the high intensity interval training group or the low intensity steady state training group. Therefore, the hypothesis that high intensity exercise produces a greater loss of body weight than low intensity steady state training is rejected. However, it was found that high intensity interval training produced a greater amount of fat loss and decrease in body fat percentage, than low intensity steady state training. The hypothesis that high intensity interval training leads to a greater loss of fat mass than low intensity steady state training is therefore not rejected.

Although both caloric expenditure during exercise and average exercise intensity were identical for both groups, caloric expenditure due to exercise was greater with high intensity interval training because of the increase it caused in acute RMR. While the increase in acute RMR was merely 74 kcal/day, this would equate to 222 kcal/week or 1776 kcal over an 8-week period, assuming that the acute RMR would not change with training status. When added to the 7200 kcal expended during the exercise sessions, this equals 8976 kcal, the equivalent of 1.2 kg of fat. The high intensity interval training group lost ~2.3 kg of fat, so it is possible that the additional fat loss could have come from an increased RMR past 24 hours. There is also a

possibility of other factors that may have led to the remainder of the fat loss. The six subjects in the high intensity interval training group who returned the dietary recall at both the beginning and end of the training period had a 238 kcal/day decrease in caloric intake from pre to post (1717 ± 520 kcal/day to 1479 ± 480 kcal/day; NS). Although this is not statistically significant due to large standard deviations, this difference could have great practical implications if it were constant throughout the training period. However, it is also possible that any changes were unique only to the three random, consecutive days measured by the dietary recalls and did not take place throughout the study.

Other responses may also have been effected by high intensity interval training and are potential topics for future research. Many researchers have found a decrease in dietary induced thermogenesis (DIT), indicative of greater glucose uptake as glycogen, in highly trained individuals (LeBlanc, Mercier, & Samson, 1984; Poehlman, Melby, & Badylak, 1988; Poehlman, Melby, Badylak, & Calles, 1989). While no difference in DIT has been found between untrained and moderately trained individuals, there is no data as to whether DIT decreases as fitness levels increase, which occurred in the high intensity interval training group. Circulating leptin has been found to play a large role in RMR and substrate utilization in women (Toth, Stites, & Poehlman, 1999), so the effect of high intensity interval training on leptin circulation would need to be examined in the future. Other hormones such as insulin and growth hormone, both of which effect fat oxidation could be effected by high intensity interval training and would need to be studied in further research.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

With a growing rate of obesity in the United States, it is necessary to find a way to help alleviate the problem. The typical way that this is done is to alter the energy balance or substrate partitioning of those prone to becoming overweight. This can be done by either decreasing caloric intake or increasing caloric expenditure. A person's caloric intake can be reduced by controlling his or her diet. Caloric expenditure is generally altered through exercise or increasing one's daily physical activity, i.e. yard-work. Due to hormonal differences that make it more difficult for women to lose weight than men, it is necessary to find a modality that will greatly enhance weight loss in women. The purpose of this study was to determine the role of exercise intensity on total daily energy expenditure and weight/fat loss in women. It was hypothesized that 1) high intensity interval training would produce a greater loss of total body weight than low intensity steady state training; 2) high intensity interval training would produce a greater loss of fat mass than low intensity steady state training; and 3) high intensity interval training would produce a greater increase in resting metabolic rate (RMR) 24 hours following an exercise session than low intensity steady state training.

To test these hypothesis, after subject drop-out was accounted for, 15 female subjects, ages 18 to 45, completed an 8-week training program. Seven subjects were randomized into a high intensity training group that exercised at ~95% of VO_2max for 2 minutes alternating with 3 minutes at ~30% of VO_2max (an average of ~55 of VO_2max). Eight subjects were randomized into a low intensity steady state training group that exercised at ~50% of VO_2max for the

duration of the exercise session. The duration of exercise varied so that each subject would burn

300 kcal per exercise session regardless of the treatment group.

Both before and after the training period, subjects were tested for body weight, body

composition, VO$_2$max, and resting metabolic rate (RMR). Body composition was tested using

hydrostatic weighing, BIA, and DEXA. Due to its multi-component model, the body

composition measure used in the final analysis was DEXA. VO$_2$max was tested midway through

the treatment in order to adjust the subjects' workloads if necessary. Resting metabolic rate was

tested within 24 hours post exercise during the first 2 weeks of exercise to determine the acute

affects of exercise on RMR.

A trend towards significance was found in the reduction of body fat percentage of the

high intensity interval training group. While this change was not significant, it is likely that

significance would have been found if the study was longer in duration. A significant decrease

was found, however, in the fat weight of the high intensity interval training group. Not only

were no such differences found in the low intensity steady state group, but also there was a

significant difference between groups for the change in both body fat percentage and fat weight.

This difference indicates the enhanced capability of high intensity interval training as opposed to

low intensity steady state training to promote fat loss.

No changes were found in RMR from pretest to posttest for either group. However, there

were significant increases in RMR and in resting VO$_2$/kg taken within 24 hours of a high

intensity interval training session within the first 2 weeks of exercise. No such change was

found in the low intensity steady state group. Although there was no between group difference

in the magnitude of change in acute RMR, it is possible that this change in acute RMR may

explain a portion of the difference in fat loss between the two groups. This change in RMR 24

hours after high intensity interval training indicates the need for adequate periods of high intensity exercise to be conducted regularly to keep RMR elevated. The lack of pre- to posttest differences shows that this is only a temporary effect.

High intensity interval training also produced a significant increase in VO_2max whereas the low intensity steady state training did not. Furthermore, the percent change in VO_2max between the groups was also significantly different. An increased VO_2max plays a great role in weight loss in that with an increase in VO_2max, a person will be able to expend more calories for a given relative intensity. In the current study, because adjustments in workload in duration were made in relation to an increase in VO_2max, exercise intensity was the main exercise related metabolic factor distinguishing the two groups.

Conclusions

No significant change was found in body weight for either group. Therefore, the hypothesis that high intensity interval training would produce greater loss of total body weight than low intensity steady state training is rejected. This finding could be due to the lack of caloric restriction involved in the treatment. The fact that no weight change occurred adds to the general evidence that a more frequent exercise program, caloric restriction, or both are needed to lose a significant amount of weight.

Although a significant amount of weight loss did not occur, a loss of fat did occur in the high intensity interval training group, leading to acceptance of the hypothesis that high intensity interval training will produce a greater loss of fat mass than low intensity steady state training. A trend for a reduction in body fat percentage as well significance in reduction of fat weight occurred in the high intensity interval training group. These changes did not occur in the low

intensity steady state training group. Moreover, significance was found in the difference in the

magnitude of the change between groups for both body fat percentage and fat weight. The

reason for the significance in change is because the low intensity steady state training group had

a slight gain in fat weight and body fat percentage. These findings indicate that high intensity

interval training produces a greater amount of fat loss than low intensity steady state training.

Although no significance was found in an increase in fat-free mass in the high intensity interval

training group, the fact that fat loss occurred while weight loss did not indicates that the high

intensity interval training group increased muscle mass to the point where weight loss would not

occur. The difference in change in body composition between groups contradicts the conclusion

of Grediagin et al. (1995) that weight and fat loss is a function of caloric cost of exercise. If that

is the case, then no difference at all should be found in body composition between the two

groups. However, even with the caloric cost of exercise held constant, a difference was found

between the two groups. For a difference to occur between groups, it is necessary for exercise to

produce a change that would facilitate weight loss. Possible candidates for the cause of this

change include an increase in RMR within 24 hours of exercise, at least in the initial stages of

training, as well as possible post-exercise changes in glycogen storage, substrate partitioning,

and anabolic hormone stimulation.

Even though both training groups exercised at an average intensity of 50% of VO_2max,

high intensity interval training produced a significant acute increase in RMR 24 hours following

an exercise session. This cannot be said of the low intensity steady state training group.

Therefore, the hypothesis that high intensity interval training will produce a greater increase in

resting metabolic rate (RMR) 24 hours following an exercise session than low intensity steady

state training is accepted. These findings indicate that a high intensity interval training program

on a regular basis will promote a continual increase in energy expenditure greater than low intensity steady state training will, at least in the initial stages of training. However, because subjects engaged in little or no cardiovascular exercise prior to the treatment, it is possible that this change only occurs as an early training adaptation and is not present in trained individuals. The absence of a change from pretest to posttest indicates that while the change produced by high intensity interval training is significant, it is only temporary, necessitating the need for regular exercise at an intensity great enough to produce a change in RMR. To determine if increased fitness plays a role in this acute change in RMR, it will be necessary to test this hypothesis against a group of trained subjects in a future study.

Although not one of the original research hypotheses, it is also concluded from the present study that high intensity interval training leads to an increase in VO_2max whereas low intensity steady state training does not. Significance was found not only in the pre to post increase in VO_2max in the high intensity interval training group, but there was also significance in the magnitude of the change between groups. This finding indicates that if training intensity does not exceed 50% of VO_2max an increase in VO_2max in obese yet active pre-menopausal women is unlikely and that high intensity interval training exercise may increase fitness at a greater rate than low intensity steady state in this population. In turn, increased fitness will lead to greater caloric expenditure at a given relative intensity due to the increased absolute workload, thus enhancing weight loss.

<div align="center">Recommendations</div>

It terms of exercise as a means of weight control, it appears evident that high intensity interval training may produce a change in fat weight and body composition not found in low intensity interval training, especially when a longer training period is used. It is unlikely that

most exercise participants, especially beginners, will be able to sustain a high intensity over a long duration; therefore, interval training is recommended because it will allow the participant to rest between high intensity intervals. This type of exercise will need to be done at least every other day in order to maintain an elevated RMR. The addition of caloric restriction appears to be necessary in order to decrease total body weight in addition to fat weight. The addition of resistance training may also help increase fat loss along with increased fat free weight, but this is an area where further research is needed.

Other recommendations for further research include using a similar mode of training with a similar population and determining post-exercise glycogen storage, substrate partitioning, and hormonal stimulation, all of which affect fat metabolism. The increase in acute RMR that accompanied high intensity interval training only accounted for a portion of the fat weight lost during the course of the study, so it is likely that other factors are involved in the change that was found. No significant pre-post differences were found in caloric intake; therefore, high intensity interval training could also be producing other physiological changes that cause it to be a better weight loss modality than low intensity steady state exercise.

Future research should also examine the relationship in fitness and acute rise in RMR. It is possible that an obese, but yet more highly trained, population would not experience the increase found in a relatively sedentary group of subjects. A similar training protocol with strict dietary control may also be an option for future research. Although no significant difference was found in caloric intake, a caloric deficit, even if statistically non-significant, over a long period of time can easily produce a change in weight. It is therefore necessary to ensure that a strict diet is maintained from the beginning to the end of the treatment.

BIBLIOGRAPHY

BIBLIOGRAPHY

References marked with an asterisk (*) indicate studies included in a meta-analysis but not directly referenced.

American College of Sports Medicine. (1995). <u>ACSM's guidelines for exercise testing and prescription</u> (5th ed. pp. 53-54, 62-64). Baltimore: Williams & Wilkins.

Bielinski, R., Schutz, Y., & Jéquier, E. (1985). Energy metabolism during the postexercise recovery in man. <u>American Journal of Clinical Nutrition, 42</u>, 69-82.

Broeder, C. E., Brenner, M., Hofman, Z., Paijmans, I. J. M., Thomas, E. L., & Wilmore, J. H. (1991). The metabolic consequences of low and moderate intensity exercise with or without feeding in lean and borderline obese males. <u>International Journal of Obesity, 15</u>, 95-104.

Broeder, C. E., Burrhus, K. A., Svanevik, L. S., & Wilmore, J. H. (1992a). The effects of aerobic fitness on resting metabolic rate. <u>American Journal Clinical Nutrition, 55</u>, 795-801.

Broeder, C. E., Burrhus, K. A., Svanevik, L. S., & Wilmore, J. H. (1992b). The effects of either high-intensity resistance or endurance training on resting metabolic rate. <u>American Journal of Clinical Nutrition, 55</u>, 802-810.

Bullough, R. C., Gillette, C. A., Harris, M. A., & Melby, C. L. (1995). Interaction of acute changes in exercise energy expenditure and energy intake on resting metabolic rate. <u>American Journal of Clinical Nutrition, 61</u>, 473-481.

Coggan, A. R., & Williams, B. D. (1995). Metabolic adaptations to endurance training: Substrate metabolism during exercise. In M. Hargreaves (Ed.), <u>Exercise metabolism</u> (pp. 177-210). Champaign, IL: Human Kinetics.

Glantz, S. A. (1992). <u>Primer of biostatistics</u> (3rd ed). New York: McGraw-Hill.

65

Gleim, G. W. (1993). Exercise is not an effective weight loss modality in women. Journal of the American College of Nutrition, 12, 363-367.

Gorostiaga, E. M., Walter, C. B., Foster, C., & Hickson, R.C. (1991). Uniqueness of interval and continuous training at the same maintained exercise intensity. European Journal of Applied Physiology, 63, 101-107.

Grediagin, A., Cody, M., Rupp, J., Benardot, D., & Shern, R. (1995). Exercise intensity does not effect body composition change in untrained, moderately overfat women. Journal of the American Dietetic Association, 95, 661-665.

*Hammer, R. L., Barrier, C. A., Roundy, E. S., Bradford, J. M., & Fisher, A. G. (1989). Calorie restricted low-fat diet and exercise in obese women. American Journal of Clinical Nutrition, 49, 77-85.

Heini, A. F. & Weinsier, R. L. (1997). Divergent trends in obesity and fat intake patterns: The American paradox. American Journal of Medicine, 102, 259-264.

*Hill, J. O., Schlundt, D. G., Sbrocco, T., Sharp, T., Pope-Cardle, J., Stetson, B., Kaler, M., & Heim, C. (1989). Evaluation of an alternating-calorie diet with and without exercise in the treatment of obesity. American Journal of Clinical Nutrition, 50, 248-254.

Hunter, G. R., Weinsier, R. L., Bamman, M. M., & Larson, D. E. (1998). A role for high intensity exercise on energy balance and weight control. International Journal of Obesity Related Metabolic Disorders, 22, 489-493.

Keim, N. L., Barbieri, T. F., Van Loan, M. D., & Anderson B. L. (1990). Energy expenditure and physical performance in overweight women: response to training with and without caloric restriction. Metabolism, 39, 651-658.

Kempen, K. P., Saris, W. H., & Westerterp K. R. (1995). Energy balance during and 8-wk energy-restricted diet with and without exercise in obese women. <u>American Journal of Clinical Nutrition, 62</u>, 722-729.

LeBlanc, J,. Mercier, P., & Samson, P. (1984). Diet-induced thermogenesis with relation to training state in female subjects. <u>Canadian Journal of Physiology and Pharmacology, 62</u>, 334-337.

Lohman, T.G (1996). Dual energy x-ray absorptiometry. In A. F. Roche, S. B. Heymsfield, & T. G. Lohman (Eds.), <u>Human body composition</u>. Champaign, IL: Human Kinetics.

Maehlum, S., Grandmontagne, M., Newsholme, E. A., & Sejersted, O. M. (1986). Magnitude and duration of excess postexercise oxygen consumption in healthy young subjects. <u>Metabolism,35</u>, 425-429.

McArdle, W. D., Katch, F. I., & Katch, V. L. (1996). <u>Exercise physiology: Energy, nutrition, and human performance</u> (4th ed.; pp. 151-152, 408-411, 541-542). Baltimore: Williams & Wilkins.

National Institutes of Health (1998a). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. <u>Executive Summary, June</u>. vi-xxvi.

National Instititutes of Health (1998b). First federal obesity guidelines released. <u>NIH News Release</u>. June 17, 1998.

Overend, T. J., Paterson, D. H., & Cunningham, D. A. (1992). The effect of interval and continuous training on the aerobic parameters. <u>Canadian Journal of Sport Science, 17</u>, 129-134.

*Pavlou, K. N., Steffee, W. P., & Lerman, R. H. (1985). Effects of dieting and exercise on lean body mass, oxygen uptake, and strength. Medicine and Science in Sports and Exercise, 17, 466-471.

Poehlman, E. T., LaChance, P., Tremblay, A., Nadeau, A., Dussault, J., Theriault, G., Despres, J., & Bouchard, C. (1989). The effect of prior exercise and caffeine ingestion on metabolic rate and hormones in young adult males. Canadian Journal of Physiology and Pharmacology, 67, 10-16.

Poehlman, E. T., Melby, C. L., & Badylak, S. F. (1988). Resting metabolic rate and postprandial thermogenesis in highly trained and untrained males. American Journal of Clinical Nutrition, 47, 793-798.

Poehlman, E. T., Melby, C. L., Badylak, S. F., & Calles, J. (1989). Aerobic fitness and resting energy expenditure in young adult males. Metabolism, 38, 85-90.

Pollock, M. L., Gaesser, G. A., Butcher, J. D., Despres, J., Dishman, R. K., Franklin, B. A., & Garber, C. E. (1998). The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Medicine and Science in Sport and Exercise, 30, 975-981.

Poole, D. C., & Gaesser, G. A. (1985). Response of ventilatory and lactate thresholds to continuous and interval training. Journal of Applied Physiology, 58, 1115-1121.

Racette, S. B., Schoeller, D. A., Kushner, R. F., Neil, K. M., & Herling-Iaffaldano, K. (1995). Effects of aerobic exercise and dietary carbohydrate on energy expenditure and body composition during weight reduction in obese women. American Journal of Clinical Nutrition, 61, 486-494.

Sedlock, D. A., Fissinger, J. A., & Melby, C. L. (1989). Effect of exercise intensity and duration on postexercise energy expenditure. Medicine and Science in Sports and Exercise, 21, 662-666.

Shinkai, S., Watanabe, S., Kurokawa, Y., Torii, J., Asai, H., & Shephard, R. J. (1994). Effects of 12 weeks of aerobic exercise plus dietary restriction on body composition, resting energy expenditure and aerobic fitness in mildly obese middle-aged women. European Journal of Applied Physiology, 68, 258-265.

Tabata, I., Nishimura, K., Kouzaki, M., Hirai, Y., Ogita, F., Miyachi M., & Yamamoto, K. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO$_2$max. Medicine and Science in Sports and Exercise, 28, 1327-1330.

Toth, M. J., Sites, C. K., & Poehlman, E. T. (1999). Hormonal and physiological correlates of energy expenditure and substrate oxidation in middle-aged premenopausal women. Journal of Clinical Endocrinology and Metabolism, 84, 2771-2775.

Tremblay, A., Simoneau, J.-A., & Bouchard, C. (1994). Impact of exercise intensity on body fatness and skeletal muscle metabolism. Metabolism, 43, 814-818.

Treuth, M. S., Hunter, G. R., & Williams, M. (1996). Effects of exercise intensity on 24-h energy expenditure and substrate oxidation. Medicine and Science in Sports and Exercise, 28, 1138-1143.

Webb, P. (1986) 24-hour energy expenditure and the menstrual cycle. American Journal of Clinical Nutrition, 44, 614-619.

Westerterp, K. R. (1998). Alterations in energy balance with exercise. American Journal of Clinical Nutrition, 68, 970S-974S.

Willis, J. D., & Campbell, L. F. (1992). <u>Exercise psychology</u> (pp. 19-22). Champaign, IL:

Human Kinetics.

Wilmore, J. H., & Costill, D. L. (1994). <u>Physiology of sport and exercise</u> (pp. 536-541).

Champaign, IL: Human Kinetics.

APPENDICES

Appendix A:
Informed Consent

Principal Investigators

Jeff King	Lynn B. Panton, Ph.D.	Craig E. Broeder, Ph.D.
P.O. Box 70654 PEXS	P.O. Box 70654 PEXS	P.O. Box 70654 PEXS
(423) 439-4265	(423) 439-5260	(423) 439-5380

Title of Project

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

This Informed Consent will explain about being a research subject in an experiment. It is important that you read this material carefully and then decide if you wish to be a volunteer. During this Informed Consent process I will thoroughly explain in laymen terms everything to you. There may be some terms in this document that may be unfamiliar to you. Please identify these terms and they will be explained to you. I will be happy to answer any questions that you may have.

Purpose of the Research

The purpose of this project is to compare the effects of high-intensity interval versus low-intensity steady-state walking on weight loss and body composition in overweight women.

Duration

The duration of the study will be approximately 12 weeks. There will be 2 weeks of testing, followed by an 8-week high or low intensity walking program or an 8-week control period with no exercise, followed by another 2 weeks of testing. For those individuals involved in the walking program there will be a time commitment of 40-60 min 3 times per week. If you are not currently exercising we ask you not to start a program until the end of the study. You are free to withdraw from the study at any time.

Exclusion Criteria

To participate in this study you must be between 18 and 40 years of age. You must be at least 30% overweight, which will be determined in the beginning of the study. You must be weight stable, non-smokers, not pregnant nor lactating and not taking any medications other than birth control pills or inhalers as needed. You will not be able to participate if you have any medical conditions that would limited your ability to participate in exercise

Revision 12-24-98

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

Principal Investigators: Jeff King, Lynn B. Panton, Ph.D., Craig E. Broeder

testing or in a high or low intensity walking program. Examples of conditions that may limit your ability to participate are high blood pressure (>160/90 mmHg), diabetes (high blood sugar), heart problems (irregular heart beats, circulation problems, and/or angina), poorly controlled asthma or lung disease, knee, ankle, or joint problems.

Procedures

General Design. Data collection will occur during several test sessions over a 2-week period. You will be chosen by chance, like flipping of a coin, to either a control group, a high-intensity interval walking group, or a low-intensity steady-state walking group. The control group will be asked to maintain their lifestyles as usual over the 8-week period. After the 8 weeks of training or control period all subjects will be retested on the tests that were taken at the beginning of the study. This final testing will take another 2 weeks. You will be required to keep a daily food intake log beginning two weeks prior to the start of the research protocol and continuing throughout the duration of the study.

Data Collection. The type of data that will be collected from you will include completion of questionnaires on your medical history, nutrition, and exercise habits. Measurements will also be taken on body composition (body fat), height, weight, girth, bone density (bone thickness), resting and exercise blood pressures, resting and exercising heart rates (electrocardiograms), and resting and exercising metabolic measurements. Resting and metabolic measurements are taken while you are resting or exercising and indirectly measures how hard your body works during rest and exercise.

Questionnaires. Questionnaires and interviews will consist of sociodemographic information, health history, exercise and diet history.

Body Composition. Body composition measurements will include height, weight, circumferences, bioelectrical impedance, underwater weighing, and bone density. Circumference measurements will be taken with a tape measure around your arms, shoulders, hips, abdomen, thigh, and waist.

Bioelectrical impedance is a method of determining body fat and muscle mass. During this test you will lie down on a stretcher and 2 sets of electrodes will be placed on your right hand and foot. A current is then passed between the set of electrodes to measure your

Revision 12-24-98

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

Principal Investigators: Jeff King, Lynn B. Panton, Ph.D., Craig E. Broeder

body composition. The current can not be felt and is not dangerous in any way. This test is done routinely in many weight loss centers.

Underwater weighing also measures body fat and muscle mass. During this test you will be asked to wear a swimsuit or shorts and a jogging bra. You will be asked to sit in a chair that is suspended from a scale in a tank of warm water. You will be asked to blow out as much air from your lungs and then slowly go under the water. A measurement of your body weight can then be made. You will have as much time as you need to become accustomed to the procedures and the underwater weighing tank.

Bone thickness (bone density) will be evaluated by Dual-Energy X-ray Absorptiometry (DEXA). Bone densities will be taken at the Women's Pavilion of Sycamore Shoals Hospital in Elizabethon, TN. During the evaluation of bone density you will lie still on an elevated table while a bone scan is taken. The procedure is routinely done, is painless and will take approximately 15 minutes to complete.

Resting Metabolic Rate. Your resting metabolic rate (RMR) will be measured in the morning after a 12 hour fast. You will be asked not to perform exercise for at least 48 hours prior to the test. You will be transported by car to the testing center and will lie down and rest for 30 minutes prior to the test. A face mask will be positioned over your nose and mouth to measure the air that you exhale. By measuring the air you exhale we can determine the amount of energy your body uses at rest. This test will take 30 minutes to complete. This test will also be completed again, for those of you that are exercising, after the first day of your exercise session. This will be done to evaluate if exercise affects the energy your body uses at rest.

Maximal Oxygen Uptake.
Maximal oxygen uptake will be measured while you undergo a graded exercise stress test on a treadmill. This also measures the energy your body uses but during exercise. You will be asked to walk on the treadmill as long as you can. When you become fatigued and no longer want to walk we will stop the test. During this test we will be monitoring your heart rate and blood pressure. We will monitor your heart rate by placing electrodes on your chest and taking pictures of the activity of your heart. This is called a 12-lead electrocardiogram and is a test similar to the test you can get in a physician's office called a stress test. Your blood pressure will be measured with a cuff on your upper arm every 2 minutes. If your blood pressure gets too high (220/110 mmHg) or your heart gets an

Revision 12-24-98

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

Principal Investigators: Jeff King, Lynn B. Panton, Ph.D., Craig E. Broeder

irregular rhythm we will stop the test. The grade and speed of the treadmill will be slowly increased until you request to stop or signs or symptoms of heart problems occur. Each stage of the treadmill test will be 1 minute in duration. The initial stage will allow you to warm-up by walking at 1.7 mph at 6% grade. The second stage increases the speed to 2.2 mph. After stage 2, either the grade increases by 2% or the speed increases by 0.4 mph until the treadmill is at a 14% grade. At that point, the speed will be increased by 0.4 mph every minute until the test is completed. Your maximal oxygen consumption will be measured by placing a mouth piece in your mouth and collecting the expired air. The air that is collected is routed by plastic tubing that is attached to the mouth piece through a metabolic cart that analyzes the gas and calculates the energy your body uses during exercise.

Training. After you complete the two weeks of initial testing you will begin the training phase of the study. You will be chosen by chance, like flipping of a coin, to either a control group, a high-intensity interval walking group, or a low-intensity steady-state walking group. If you are in the control group you will be asked to maintain your lifestyle as usual over the 8-week period. The two exercise groups will exercise on a treadmill three times a week for 8 weeks. Exercise intensity (how hard you work) will be based on the treadmill test. Increases in intensity will not be made by increasing the speed of the treadmill but rather by increasing the grade. For training you will select a comfortable walking speed. The grade of the treadmill will be adjusted to meet your required intensity.

If you are in the low intensity steady-state walking group you will exercise at 50% of your maximal energy expenditure for a duration that will expend 300 kcal (a measure of energy your body uses). This will be determined from your body weight and using results from the maximal oxygen uptake test. If you are in the high-intensity interval walking group you will exercise at 105% of your energy expenditure for approximately 2 minutes. After 2 minutes of high intensity walking you will walk at 0% grade for 2 to 5 minutes. Duration of exercise and intervals of high and low grades will be determined based on your weight and results from your maximal oxygen uptake test. You will also train until you expend 300 kcal. Every 2 weeks your energy expenditure during exercise will be checked by placing the mouth piece in the mouth and collecting expired gas for approximately 10 minutes. Your weight will also be monitored on a weekly basis to determine if duration needs to be altered to maintain the 300 kcal expenditure during the exercise. An additional maximal oxygen test will be completed at week 4 to adjust exercise protocols for increases in fitness levels. At the end of the study all tests that were performed at the beginning of the study will be repeated.

Revision 12-24-98

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

Principal Investigators: Jeff King, Lynn B. Panton, Ph.D., Craig E. Broeder

Possible Risks/Discomforts

During the study you may be become self-conscious about the testing of body composition. Every effort will be made to make you feel comfortable. There are no physical risks to measuring body composition by circumferences nor bioelectrical impedance. The underwater weighing procedures may be intimidating for those of you that are afraid of water. If you do have problems with this technique it will not be completed. Careful explanation of procedures and practice will be given to minimize fear and swallowing of any water that may occur. Bone density will be evaluated by Dual-Energy X-ray Absorptiometry (DEXA). This involves some radiation of approximately 12 mREM per spine or hip scan and 0.5 mREM per total body scan, or a total of about 25 mREM for the three scans. This is comparable to the radiation you would receive from a chest x-ray (20-50 mREM), but substantially less that a full dental x-ray (300 mREM) or an abdominal x-ray (250 mREM). The measurement of bone mineral using the DEXA is non-invasive.

The risk of cardiovascular events during the stress test and training period will be minimized by careful review of your medical history. You will not be able to participate in this study if you have any evidence of heart disease, high blood pressure, diabetes or problems with your joints. You may experience some muscle soreness after stress testing walking. Care will be taken to try and minimize soreness by thoroughly stretching before and after each exercise session.

Possible Benefits and/or Compensation

The benefits of your participation in the study will include a free battery of tests. Your results will be made available to you and your personal physician. You will also be able to see how your fitness levels compare to individuals your age in the general population. You may also benefit by losing weight and becoming more physically fit. A nutritionist will also be made available to help counsel you on proper nutrition at the end of the study.

Contact for Questions

If you have any questions or research related problems at any time, you may call Lynn Panton, Ph.D. at 439-5260 or Craig Broeder, Ph.D. at 439-5380 . You may call the Chairman of the Institutional Review Board at 423/439-6134 for any questions you may have about your rights as a research subject.

Revision 12-24-98

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

Principal Investigators: Jeff King, Lynn B. Panton, Ph.D., Craig E. Broeder

<u>Confidentiality</u>

Every attempt will be made to see that your results are kept confidential. A copy of the records from this study will be stored in the Department of Physical Education, Exercise and Sport Sciences in room E-116 for at least 10 years after the end of this research project. The results of this study may be published and/or presented at conferences without naming you as a subject. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the East Tennessee State University/V.A. Medical Center Institutional Review Board, the Food and Drug Administration, and the ETSU Department of Physical Education, Exercise and Sport Sciences have access to the study records. Your records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above.

<p align="center">Compensation for Medical Treatment</p>

East Tennessee State University will pay the cost of emergency first aid for any injury that may happen as a result of your being in this study. They will not pay for any other medical treatment. Claims against ETSU or any of its agents or employees may be submitted to the Tennessee Claims Commission. These claims will be settled to the extent allowable as provided under TCA Section 9-8-307. For more information about claims call the Chairman of the Institutional Review Board of ETSU at 423/439-6134.

Revision 12-24-98

To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

Principal Investigators: Jeff King, Lynn B. Panton, Ph.D., Craig E. Broeder

<u>Voluntary Participation</u>

The nature demands, risks, and benefits of the project have been explained to me as well as are known and available. I understand what my participation involves. Furthermore, I understand that I may withdraw from the study at any time without penalty. I have read, or have had read to me, and fully understand the consent form, I sign it freely and voluntarily. A signed copy has been given to me. Your study record will be maintained in strictest confidence according to current legal requirements and will not be revealed unless required by law or as noted above.

_____

Signature of Volunteer   Date

_____

Signature of Investigator   Date

_____

Signature of Witness   Date

Revision 12-24-98

Appendix B:
Internal Review Board Approval

Narrative Description Guidelines

1.   **Project Title**
        To compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women.

2.   **Place to be Conducted**
        Testing and training will be carried out in the Human Performance Laboratory located in the Mini Dome at East Tennessee State University. Some of the training sessions may be carried out at the Johnson City Medical Center Wellness Center.

3.   **Objectives**
        The objective of this project is to compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in overweight women

4-5.   **Summary and Specific Role of Human Subjects**

        Researchers have attempted to determine the most suitable means of combating the growing problem of obesity in America. Most studies agree that exercise is an important component in any weight loss program. Even though studies may not find dramatic decreases in weight loss, they have found that exercise preserves lean mass and increases total daily energy expenditure (TDEE), which may facilitate weight loss over an extended period of time. However, the research does not agree on the most beneficial form of exercise. It has been found that continuous steady state exercise below the lactate threshold for prolonged periods is as beneficial for weight loss as higher intensity exercise (Grediagin, Cody, Rupp, Benardot, & Shern, 1995). Conversely, interval training above lactate threshold for shorter periods of time has been found to be more beneficial for increasing TDEE (Treuth, Hunter, & Williams, 1996) which in turn yields greater caloric expenditure throughout the day.   Therefore, the purpose of the present study is to compare the effects of high-intensity interval versus low-intensity steady-state training on weight loss and body composition in obese pre-menopausal women.

        Subjects. Subjects for this study will be recruited through flyers and by word of mouth through the Johnson City and surrounding areas.   The primary criterion for subject selection is that all subjects will be clinically obese per-menopausal women. Obesity in women is defined as having a body fat percentage greater than 30%. To avoid possible maturation due to the beginning of menopause, all subjects will be between 18 and 40 years of age. All subjects will be weight stable, non-smokers, not pregnant nor lactating and not taking any medications other than birth control pills. Subjects will not have any medical conditions that would be contraindicated to an exercise program or potentially hinder the effects of the exercise treatment. Subjects will be required to keep a daily food intake log beginning two weeks prior

to the start of the research protocol and continuing throughout the duration of the study. Each subject will then be given a dietary check sheet based on her food intake log in order to help her adhere to a constant diet. Approximately 30 subjects will be recruited for this study. There will be three experimental groups a control group (n=10), a high-intensity interval training group (n=10), and a low-intensity steady-state training group (n=10).

General Design. Data collection will occur during several test sessions over a 2-week period. All testing will be repeated after the 8 weeks of training.

Data Collection. The type of data collected from the participants will include scales and items measuring sociodemographic information, body composition, height, weight, girth, blood pressures, heart rates, resting metabolic rate, and maximal oxygen uptake (VO_2max).

Questionnaires. Standardized questionnaires will consist of sociodemographic information.

Body Composition. Body composition measurements will include bone density, underwater weighing, bioelectrical impedance, and circumferences. Waist-to-hip ratios will also be evaluated. This measurement was chosen due to its high correlation with ischemic heart disease, stroke, diabetes, hypertension, and all cause mortality in both men and women.

Bone density will be evaluated by Dual-Energy X-ray Absorptiometry (DEXA). This involves some radiation of approximately 12 mREM per spine or hip scan and 0.5 mREM per total body scan, or a total of about 25 mREM for the three scans. This is comparable to the radiation a person receives from a chest x-ray (20-50 mREM), but substantially less that a full dental x-ray (300 mREM) or an abdominal x-ray (250 mREM). The measurement of bone mineral using the DEXA is non-   invasive.

Underwater weighing measures body density by having the subject sit in a chair that is suspended from a scale in a tank of water. The subject is asked to blow out as much air from the lungs and then slowly go under the water. A measurement of body weight can then be made. With generalized equations body density and ultimately body fat can be calculated.

Bioelectrical impedance measures the resistance of current through the body. A very low 50 Khz current is passed through 2 sets of electrodes and resistance is measured. Fat mass, fat-free mass, and percent body fat will be determined by resistance, reactance, and impedance.

Resting Metabolic Rate. Resting metabolic rate (RMR) will be measured in the morning after a 12 hour fast. Subjects will be asked not to perform exercise for at least 48 hours prior to the test. Subjects will be transported by car to the testing center and will rest in a semirecumbent position for 30 minutes prior to the test. An air tight face mask will be positioned on the subject. Ventilation, oxygen consumption, and respiratory exchange ratio will be measured for 30 minutes. The subject will remain inactive and the noise and light level in the room will be diminished. Resting metabolic rate will also be taken the day after subjects begin their treatment protocols to evaluate the effects of acute exercise bouts on RMR.

Maximal Oxygen Uptake.   Maximal oxygen uptake (VO_2max) will be measured while subjects undergo a graded exercise stress test on a treadmill. The grade and speed of the treadmill will be slowly increased until the subjects request to stop or signs or symptoms of cardiovascular problems occur. Each stage of the treadmill test will be 1 minute in duration. The initial stage will allow subjects to warm-up by walking at 1.7 mph at 6% grade. The second stage increases the speed to 2.2 mph. After stage 2, either the grade increases by 2% or the speed increases by 0.4 mph until the treadmill is at a 14% grade. At that point, the speed will be increased by 0.4 mph every minute until the test is completed. Subject will be monitored continuously by a 12-lead electrocardiogram and blood pressure will be measured every 2 minutes. Maximal oxygen consumption will be measured by placing a mouth piece in the subject's mouth and collecting the expired air (oxygen and carbon dioxide). The air that is collected is routed by plastic tubing that is attached to the mouth piece through a metabolic cart that analyzes the gas and calculates the VO_2max.

Training. After subjects complete the 2 weeks of initial testing they will begin the training phase of the study. Subjects will be randomly assigned to one of three groups 1) a control, that will not exercise, 2) a low-intensity steady-state training group and 3) a high-intensity interval training group. The control group will be asked not to change their lifestyle over the 8-week study. The two exercise groups will exercise on a treadmill three times a week for 8 weeks. Exercise intensity will be based on the treadmill VO_2max test. Increases in intensity will not be made by increasing the speed of the treadmill but rather by increasing the grade. For training all subjects will select a comfortable walking speed and grade will be adjusted to meet the required intensity. The low intensity steady-state group will exercise at 50% of their VO_2max for a duration that will expend 300 kcal. This will be determined from their body weights and using results from their VO_2max tests. The high-intensity interval group will exercise at 105% of their VO_2max for increments lasting two minutes. After 2 minutes at 105% of VO_2max subjects will walk at 0% grade for 2 to 5 minutes. Again duration of exercise and intervals of high and low grades will be determined based on weights and results of the VO_2max tests. Again subjects will train until they expend 300 kcals. Every 2 weeks subjects VO_2 will be checked to see if subjects are training at their specified intensities. The VO_2 will be checked by placing the mouth piece in the mouth and collecting expired gas for approximately 10 minutes. Each subject's weight will also be monitored on a weekly basis to determine if duration needs to be altered to maintain the caloric

expenditure during the exercise at 300 kcal. An additional VO_2max test will be completed at week 4 to adjust exercise protocols for increases in fitness levels. At the end of the study all tests that were performed at the beginning of the study will be repeated.

6.   Specific Risks to Subjects

During the testing subjects may be become self-conscious about the testing of body composition. Every effort will be made to make the subjects feel comfortable and not embarrassed by their weight. There are no physical risks to measuring body composition by circumferences nor bioelectrical impedance. The underwater weighing procedures may be intimidating for those subjects afraid of water. If the subjects do have problems with this technique it will not be completed. Careful explanation of procedures and practice will be given to minimize fear and swallowing of any water that may occur. Bone density will be evaluated by Dual-Energy X-ray Absorptiometry (DEXA). This involves some radiation of approximately 12 mREM per spine or hip scan and 0.5 mREM per total body scan, or a total of about 25 mREM for the three scans. This is comparable to the radiation a person receives from a chest x-ray (20-50 mREM), but substantially less that a full dental x-ray (300 mREM) or an abdominal x-ray (250 mREM). The measurement of bone mineral using the DEXA is non-invasive.

The risk of cardiovascular events during the stress test and training period will be minimized by selecting young subjects less than 40 and by evaluating their medical histories. All subjects will be free of medical conditions that would be contraindicated to an exercise program such as diabetes, high blood pressure, or abnormal heart rhythms. Studies of participants in recreational sports showed 1 cardiovascular complication per 495,000 participants.

Subjects may experience some muscle soreness after stress testing and training. Care will be taken to try and minimize soreness by thoroughly stretching each participant before and after her exercise session.

7.   Benefits to Subjects

Subjects will be given a battery of tests free of charge. All results will be made available to subjects. The subjects may benefit from the exercise by losing weight and becoming more aerobically fit.

8.   Inducements

No payment will be given to subjects but a nutritionist will be made available to help counsel the subjects on proper nutrition.

9.   Subject Confidentiality

Each patient's right to privacy will be maintained. The medical information will be available for inspection by the ETSU/IRB. All information about the patient will be treated confidentially and will not be released, except as noted above, unless required by law.

10.   Informed Consent

The informed consent is attached. All subjects will have the Informed Consent explained to them and all their questions will be answered. The subject will be required to sign the Consent in order to participate in the study.

11.   Adverse Reaction Reporting

All adverse reactions will be reported verbally to the IRB chairman within 24 hours, and in writing to the IRB Board within 10 days of occurrence.

12.   Pertinent Literature

Bielinski, R., Schutz, Y., Jéquier, E. (1985). Energy metabolism during the postexercise recovery in man. American Journal of Clinical Nutrition, 42, 69-82.

Broeder, C. E., Burrhus, K. A., Svanevik, L. S., & Wilmore, J. H. (1992a). The effects of aerobic fitness on resting metabolic rate. American Journal Clinical Nutrition,55, 795-801.

Broeder, C. E., Burrhus, K. A., Svanevik, L. S., & Wilmore, J. H. (1992b). The effects of either high-intensity resistance or endurance training on resting metabolic rate. American Journal of Clinical Nutrition, 55, 802-810.

Coggan, A. R. & Williams, B. D. (1995). Metabolic adaptations to endurance training: substrate metabolism during exercise. In M. Hargreaves (Ed.), Exercise Metabolism (pp. 177-210). Champaign, IL: Human Kinetics.

Gorostiaga, E. M., Walter, C. B., Foster, C., & Hickson, R.C. (1991). Uniqueness of interval and continuous training at the same maintained exercise intensity. European Journal of Applied Physiology, 63, (2), 101-107.

Grediagin, A., Cody, M., Rupp, J., Benardot, D., & Shern, R. (1995). Exercise intensity does not effect body composition change in untrained, moderately overfat women. Journal of the American Dietetic Association, 95, (6), 661-665.

Hammer, R. L., Barrier, C. A., Roundy, E. S., Bradford, J. M., & Fisher, A. G. (1989). Calorie restricted low-fat diet and exercise in obese women. American Journal of Clinical Nutrition, 49, 77-85.

Keim, N. L., Barbieri, T. F., Van Loan, M. D., & Anderson B. L. (1990). Energy expenditure and physical performance in overweight women: response to training with and without caloric restriction. Metabolism, 39, (6), 651-658.

Overend, T. J., Paterson, D. H., & Cunningham, D. A. (1992). The effect of interval and continuous training on the aerobic parameters. Canadian Journal of Sport Science, 17, (2), 129-134.

Pavlov, K. N., Steffee, W. P., & Lerman, R. H. (1985). Effects of dieting and exercise on lean body mass, oxygen uptake, and strength. Medicine and Science in Sports and Exercise, 17, 466-471.

Racette, S. B., Schoeller, D. A., Kushner, R. F., Neil, K. M., & Herling-Iaffaldano, K. (1995). Effects of aerobic exercise and dietary carbohydrate on energy expenditure and body composition during weight reduction in obese women. American Journal of Clinical Nutrition, 61, 486-494.

Shinkai, S., Watanabe, S., Kurokawa, Y., Torii, J., Asai, H., & Shephard, R. J. (1994). Effects of 12 weeks of aerobic exercise plus dietary restriction on body composition, resting energy expenditure and aerobi fitness in mildly obese middle-aged women. European Journal of Applied Physiology, 68, (3), 258-265.

Tabata, I., Nishimura, K., Kouzaki, M., Hirai, Y., Ogita, F., Miyachi M., & Yamamoto, K. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO2max. Medicine and Science in Sports and Exercise, 28, (10), 1327-1330.

Tremblay, A., Simoneau, J.-A., & Bouchard, C. (1994). Impact of exercise intensity on body fatness and skeletal muscle metabolism. Metabolism, 43, (7), 814-818.

Treuth, M. S., Hunter, G. R., & Williams, M. (1996). Effects of exercise intensity on 24-h energy expenditure and substrate oxidation. Medicine and Science in Sports and Exercise, 28, (9), 1138-1143.

Westerterp, K. R. (1998). Alterations in energy balance with exercise. American Journal of Clinical Nutrition, 68, (4), 970S-974S.

13.   Location of Records

All data and samples will be coded numerically by subject. The master sheet for these codes and questionnaires obtained from the subjects will be retained by the principal investigator in a separate file housed in the office of the PI that is located in the Mini Dome. No names, initials, or other identifying characteristics will be reported in publication. Data will be kept for at least 10 years.

Appendix C:
Tables

Table 1: TRAINING PROTOCOL

Group	Treadmill Time	Interval Intensity	Average Intensity
ST (n=8)	51.1 ± 8.9 min*	--	~ 50%
IT (n=7)	51.0 ± 9.0 min*	2 min @ ~ 95% 3 min @ ~ 30%	~ 55%

* Statistically similar ($p \leq 0.05$)
ST: low intensity steady state training group; IT: high intensity interval training group

Table 2: PHYSICAL CHARACTERISTICS (N=15)

Variable	Interval Training Group (n=7)	Steady State Training Group (n=8)
Age (yrs)	33.0 ± 7.4 (20-39)	33.0 ± 11.5 (18-44)
Height (cm)	167.8 ± 5.6 (155.6-172.7)	166.0 ± 7.4 (157.5-180.3)
Weight (kg)	94.0 ± 24.1 (61.8-125.0)	90.9 ± 22.1 (63.9-125.9)
BMI (kg/m^2)	33.5 ± 7.3 (25.5-43.2)	33.0 ± 7.9 (24.5-48.4)

BMI: Body Mass Index
Values are mean ± standard deviation (range in parentheses)

Table 3: CHANGES IN PHYSICAL CHARACTERISTICS AFTER 8 WEEKS OF TRAINING (N=15)

Variables	Interval Training (n=7)		Steady State Training (n=8)	
	Pre	Post	Pre	Post
Body Weight (kg)	94.0 ± 24.1	92.8 ± 26.4	90.9 ± 22.1	91.6 ± 22.1
BMI (kg/m^2)	33.5 ± 7.3	33.0 ± 8.3	33.0 ± 7.9	33.3 ± 8.2
% Body Fat (%)	45.5 ± 7.8	43.5 ± 6.9‡	42.4 ± 5.2	42.9 ± 4.6
Fat Weight (kg)	44.1 ± 17.3	41.8 ± 17.3*	39.4 ± 14.1	40.1± 13.9
Fat Free Weight (kg)	49.9 ± 8.4	51.0 ± 10.0	51.5 ± 8.8	51.5 ± 8.6

Values are means ± standard deviation
‡a trend toward significant difference from pretest (p = 0.07)
*significant from pretest at $p \leq 0.01$

Table 4: CHANGES IN DIETARY CHARACTERISTICS OVER THE 8 WEEKS OF TRAINING (N=11)

Variables	Interval Training (n=6)		Steady State Training (n=5)	
	Pre	Post	Pre	Post
kcal/day	1717± 520	1479 ± 480	1479 ± 514	1392 ± 406
% CHO	48.4 ± 8.0	46.8 ± 9.5	52.2 ± 5.3	47.1 ± 10.0
% Fat	32.3 ± 7.0	33.0 ± 8.0	32.5 ± 3.5	32.8 ± 8.3
% Protein	19.3 ± 4.5	20.2 ± 2.2	15.3 ± 3.0	20.2 ± 2.7‡

Values are means ± standard deviation
‡a trend toward significant difference from pretest (p = 0.07)

Table 5: CHANGES IN METABOLIC CHARACTERISTICS (N=15)

Variables	Interval Training Group (n=7)			Steady State Training Group (n=8)		
	Pre	Acute	Post	Pre	Acute	Post
RMR (kcal/day)	1688 ± 373	1762 ± 376‡	1720 ± 337	1756 ± 408	1787 ± 397	1789 ± 390
VO_2rest (ml•min^{-1})	243 ± 54	253 ± 53*	244 ± 45	255 ± 59	258 ± 59	255 ± 52
VO_2rest/kg (ml•kg^{-1}•min^{-1})	2.63 ± 0.34	2.74 ± 0.33‡	2.71 ± 0.42	2.81 ± 0.34	2.87 ± 0.41	2.80 ± 0.31
VO_2rest/kg FFW (ml•kg^{-1}•min^{-1})	4.86 ± 0.6	5.10 ± 0.6*	4.8 ± 0.5	4.9 ± 0.5	5.0 ± 0.6	4.9 ± 0.4
RERrest	0.80 ± 0.03	0.81 ± 0.03	0.84 ± 0.11	0.78 ± 0.06	0.79 ± 0.04	0.82 ± 0.06

RMR: Resting Metabolic Rate; VO_2rest: Resting oxygen consumption;
VO_2rest/kg: Relative resting oxygen consumption;
VO_2rest/kgFFW: Resting oxygen consumption adjusted for fat free weight;
RERrest: Resting respiratory exchange ratio
Values are means ± standard deviation
‡a trend toward significant difference from pretest ($p = 0.07$)
*significant from pretest at $p \leq 0.05$

Table 6: ACUTE EFFECT OF EXERCISE ON RMR

Study	Population	Duration	Intensity	RMR Tested	RMR Change
Present study	Obese women	~51.1 min	~50%	~17 hr	None
Poehlman et al., 1989	Lean, fit males	90 min	~50%	24 & 48 hr	None
Present study	Obese women	~51 min (2 min high 3 min low)	~95% high ~30% low	~17 hr	+ 4.4%
Bielinski et al., 1985	Lean, trained males	3 hr	~50%	18 hr	+ 4.7%
Broeder et al., 1992b	Lean males, varied training	50 min	70-85%	14 hr	+ 4.8%

Table 7: ENERGY BALANCE: KCAL/DAY EXPENDED AT RMR VS. KCAL/DAY CONSUMED

Group (N=11)	Kcal/day consumed	PreRMR Kcal/day expended	Pre Energy Balance (kcal/day)	AcuteRMR Kcal/day expended	Acute Energy Balance (kcal/day)
IT (n=6)	1717 ± 520	1647 ± 392	+70 ± 647	1704 ± 520	+12 ± 638
ST (n= 5)	1479 ± 514	1908 ± 392	-429 ± 670	1956 ± 377	-477 ± 582

Values are means ± standard deviation
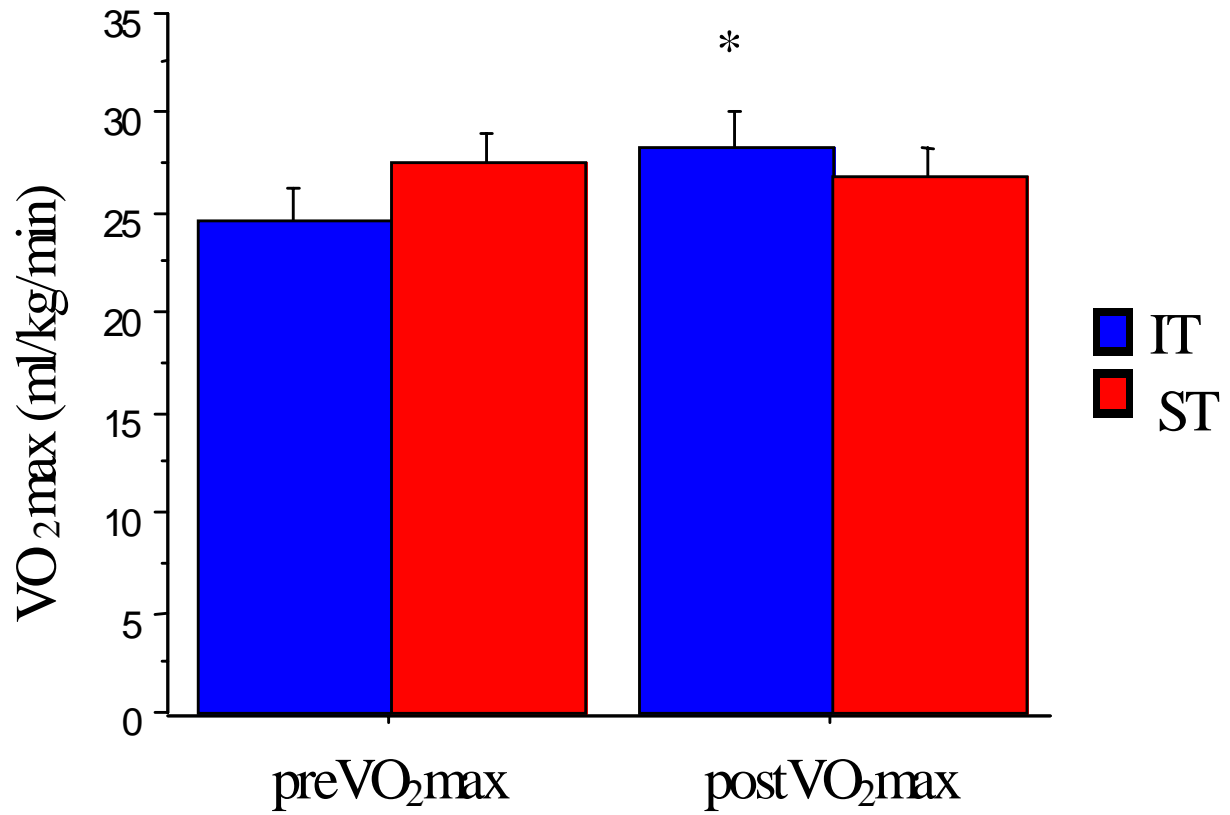No significant differences were found

Appendix D
Figures

Fig. 1: WITHIN AND BETWEEN GROUP CHANGES IN VO$_2$MAX

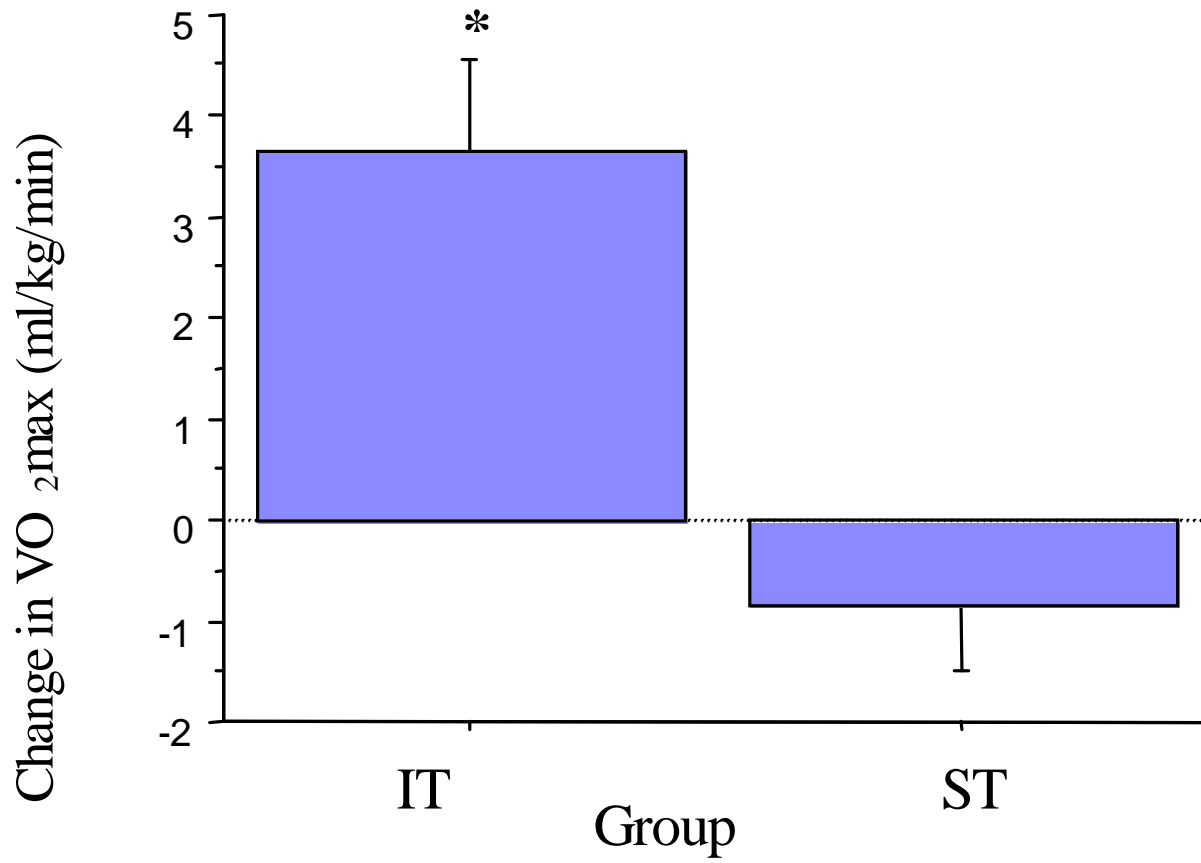*Significant from pretest (p < 0.01)

Fig. 2: DIFFERENCE IN CHANGE IN VO$_2$MAX
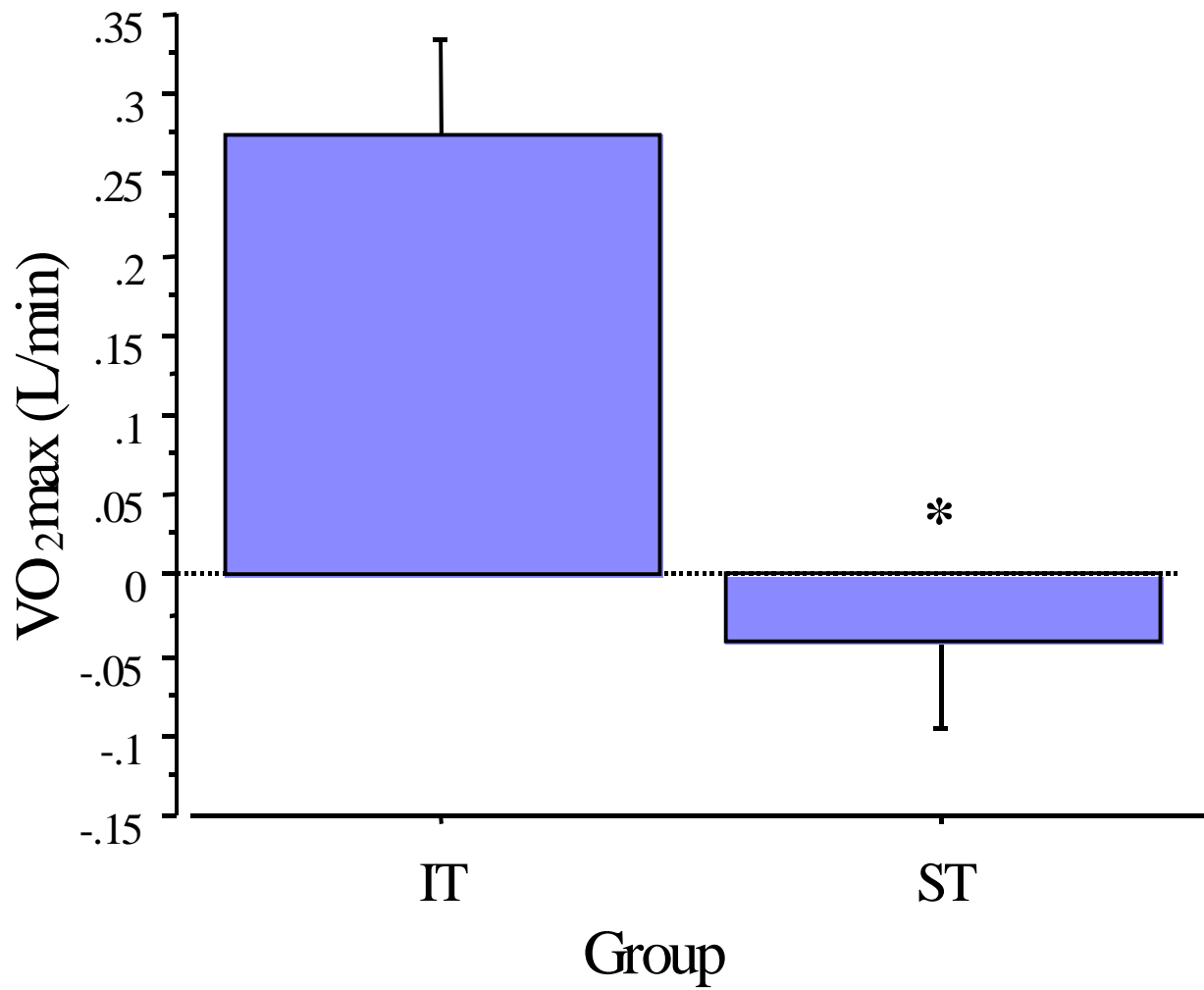
*Significant from ST ($\underline{p} < 0.001$)

Fig. 3: CHANGE IN ABSOLUTE VO$_2$MAX

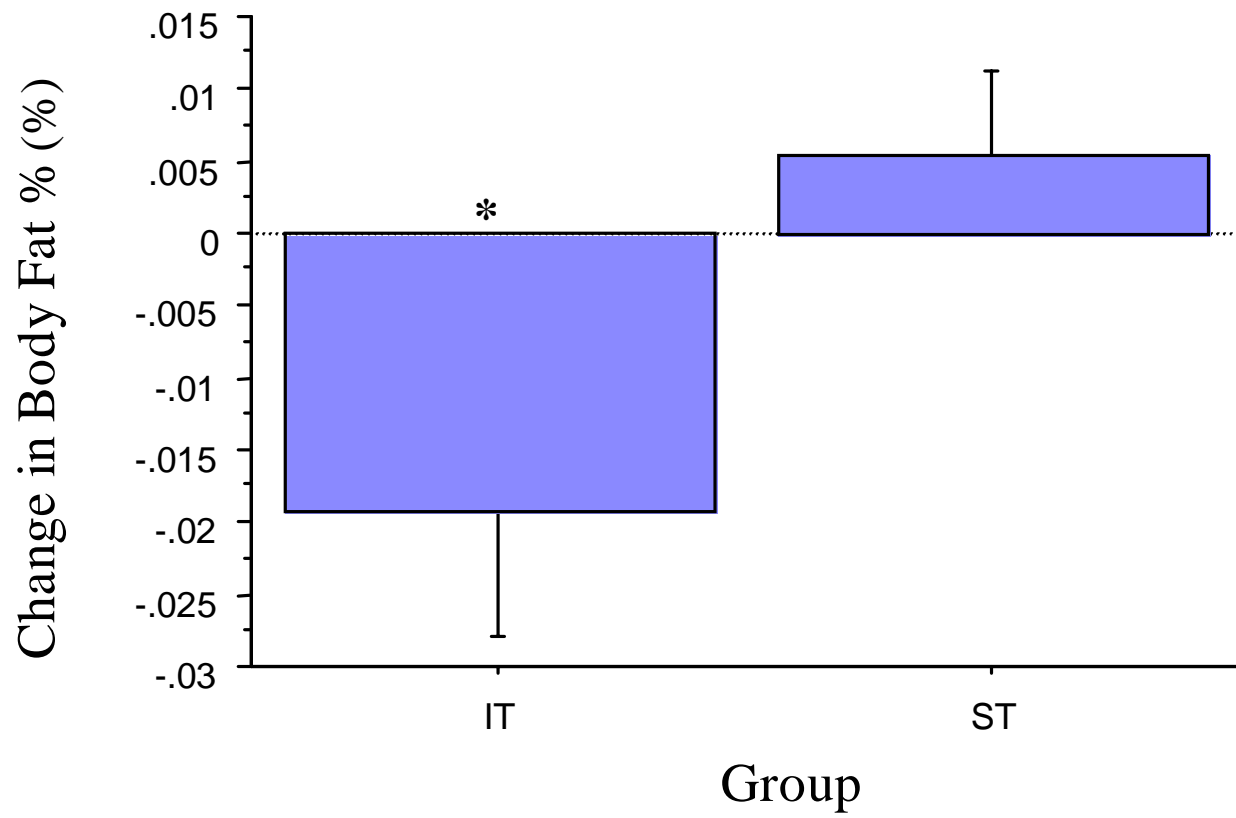*Significant from IT (p < 0.01)

Fig. 4: CHANGE IN BODY FAT PERCENTAGE
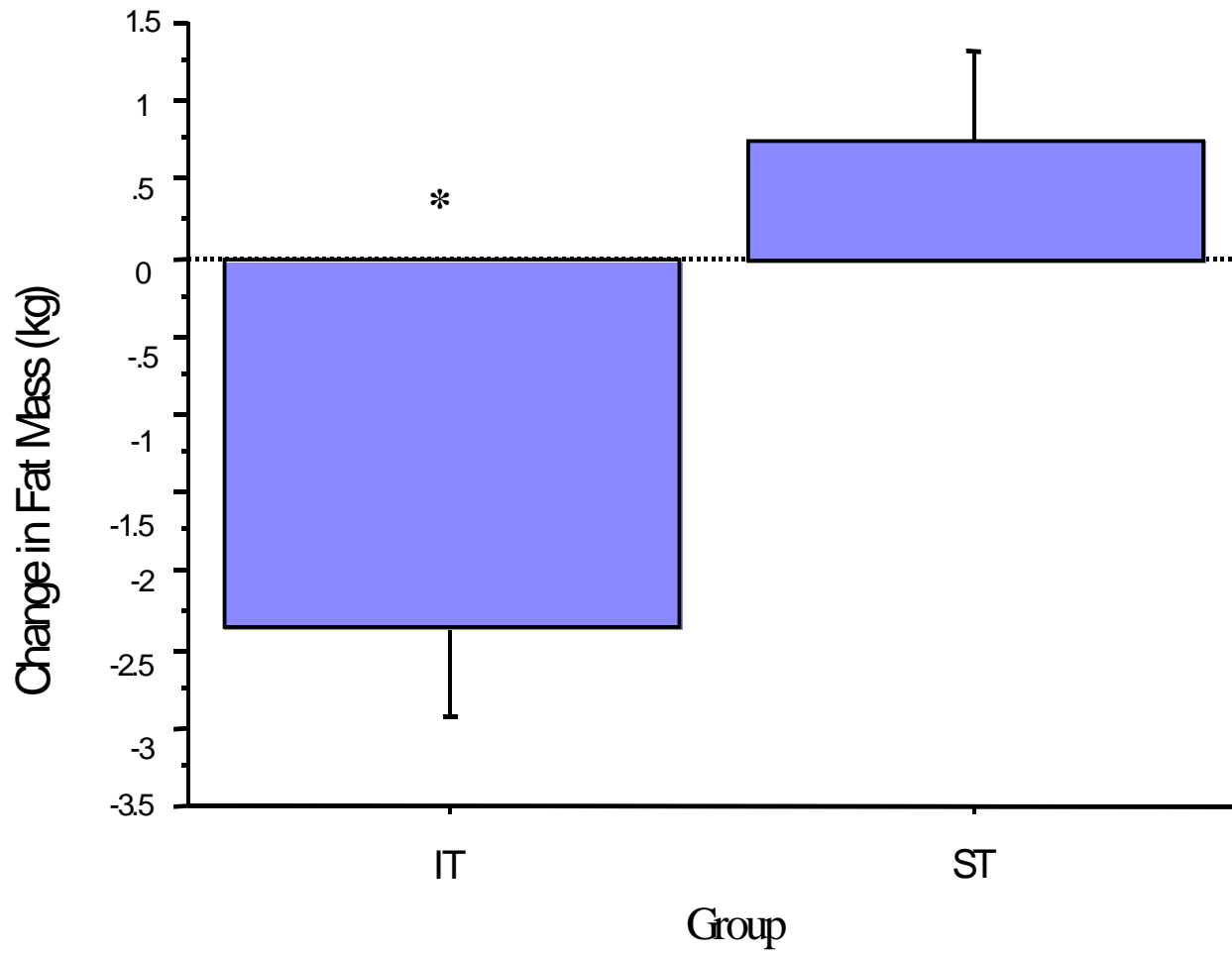
*Significant from ST (p < 0.05)

Fig. 5: CHANGE IN FAT MASS

*Significant from ST ($p < 0.01$)

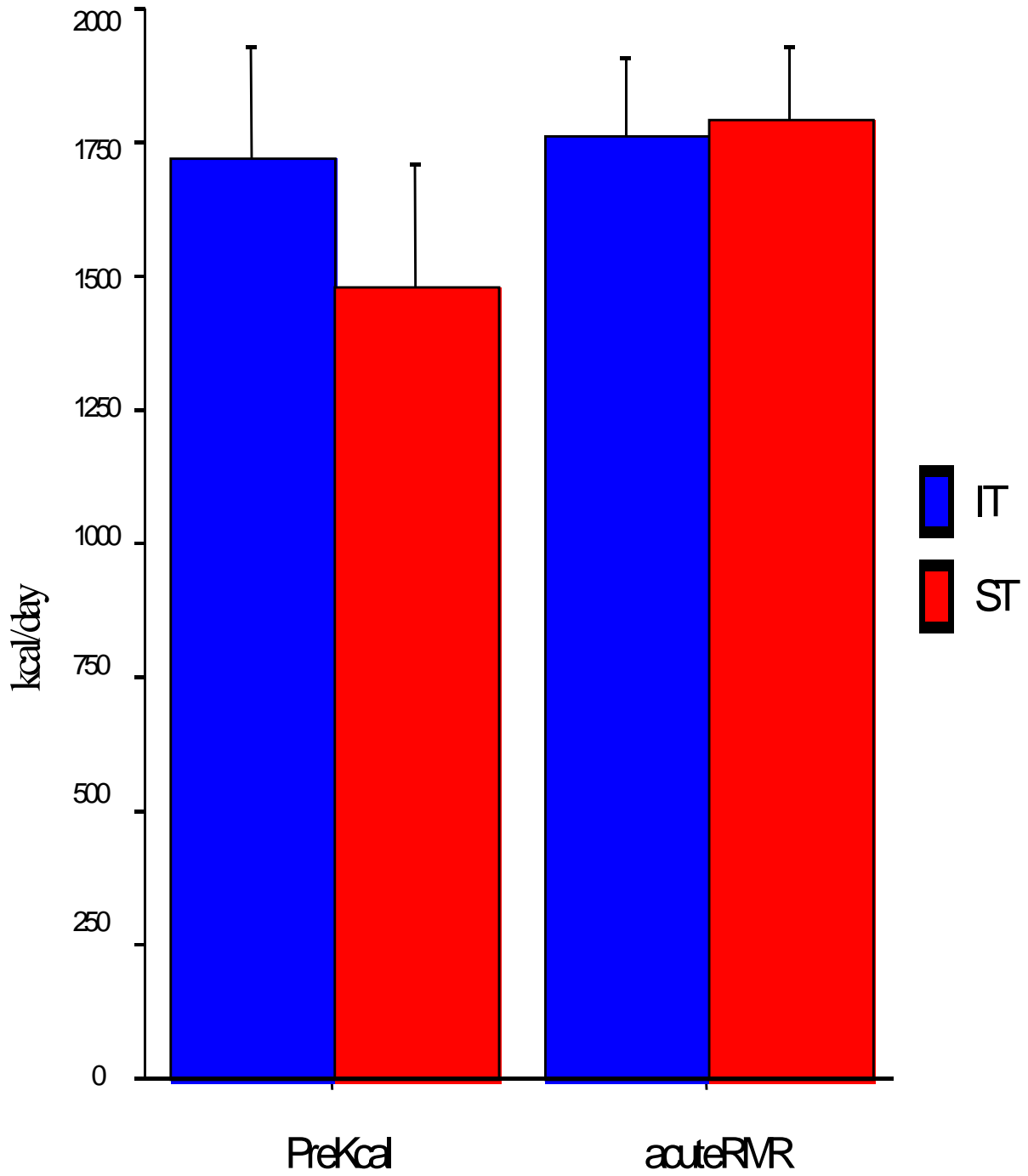Fig. 6: KCAL/DAY CONSUMED VS. EXPENDED

VITA

JEFFREY W. KING

Personal Data: Date of Birth: August 8, 1975
                Place of Birth: Johnson City, Tennessee
                Marital Status: Single

Education: David Crockett High School, Jonesborough, Tennessee

                Vanderbilt University, Nashville, Tennessee;

                     European Studies, B.A., 1997

                East Tennessee State University, Johnson City, Tennessee;

                     Physical Education, M.A., 2001

Professional

Experience: Graduate Assistant, East Tennessee State University, College of Education

                     1999-2001

Publications: King, J., Panton, L., Broeder, C., Browder, K., Quindry, J., & Rhea, L. (2001).
                     A comparison of high intensity vs. low intensity exercise on body
                     composition in overweight women. (To be presented at National ACSM,
                     June, 2001).

                King, J., Golden, J., Panton L.B., Broeder, C.E., Browder, K.D., Fogle, D.J.,
                     Cestaro-Seifer, D.J., & Seifer, F.D. (2001). Effects of 12 weeks of
                     progressive resistance training on bone density in patients with chronic
                     obstructive pulmonary disease (COPD). (Presented at Southeast ACSM,
                     January, 2001).