2006

A Comparison of the Effects of Post Exercise Basal Metabolic Rate Among Continuous Aerobic, Intermittent Aerobic, and Resistance Exercise: Implications for Weight Control

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By

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A Dissertation submitted to the
Department of Food, Nutrition, and Exercise Sciences
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Degree Awarded:
Spring Semester, 2006

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All this achievement is dedicated to my father and mother, who provide me with unlimited support and unconditioning love during the time I have been struggling here.

ACKNOWLEDGEMENTS

First of all, I would like to express my full appreciation and special gratitude to Dr. Lynn Panton for her kindness, patience and guidance, throughout my doctoral program. With out her, undoubtedly I would not have been able to achieve this significant milestone in my life. Secondly, I would like to thank the members of my dissertation committee, Dr. Robert Moffatt and Dr.Penny Gilmer for their time and expertise. Thirdly, I would like to thank my best friends, Trevor Lund and Nopawan Buatong, for helping with the editing of my work. Finally, I would like to thank all my students and subjects who came to the laboratory each night to help me and participate in my study. You all made the time I spent during this investigation a memorable and enjoyable endeavour.

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ABSTRACT

Purpose: To compare the effects of three bouts of exercise, resistance (RE), continuous aerobic (CA), and intermittent aerobic (IA), matched for energy expenditure (kcal) and rate of oxygen consumption (VO_2), on 12h post exercise metabolic rate and basal metabolic rate (BMR). Ten healthy men (age: 22 ± 2 yrs, height: 173.8 ± 11.6 cm, weight: 77.1 ± 16.4 kg, VO_2max: 34.5 6.1 ml/kg/min) were recruited to participate in this study. 12h post exercise and BMR were measured on four sessions over a four week period: control, RE, CA, and IA. For each session, subjects performed exercise at 9.00 am and returned to the laboratory at 9.00 pm to have their 12 h post exercise metabolic rate measured and to stay overnight in the laboratory, to have their BMR measured the following morning. For RE session, subjects performed one circuit of five exercises vertical butterflys, squats, toe raises, lateral pulldowns, and triceps press downs at approximatedly 50-60% of their maximal lifts. Each set was performed until failure, and followed by 60s of rest. The circuit was repeated for a total of 45 min of exercise. VO_2 was measured continuously and used for calculating the total amount of energy expenditure (216 ± 19 kcal) and average rate of VO_2 (12.5 ± 1.8 ml/kg/min). For CA, subjects cycled at a work load that produced the same average rate of VO_2 at each subject's average rate of VO_2 during the RE. For IA, subjects cycled at high intensity interval between 90%-100% of VO_2max for 30 seconds and a low intensity interval at 20-30% of VO_2max. For the low intensity interval, subjects cycled until the average rate of VO_2 in that interval matched the average rate of VO_2 during the RE. For both CA and IA, subjects cycled until spending the same amount of kcal measured during RE (exercise duration; CA: 43.2 ± 2.3; IA: 43.5 ± 1.8min). For 12h post exercise metabolic rate, RE caused greater increases in metabolic rate compared to the control (14.6%), CA (9.3%) and IA (4.4%). IA also had significantly higher metabolic rate compared to the control (9.8%) and CA (4.7%). BMR was significantly higher after RE compared to the control (15.6%), CA (12.1%), and IA (12.1%). These results suggest that RE has greater effects on BMR compared to CA and IA, indicating the importance of further research to examine a possible role for RE in controlling body weight.

CHAPTER 1
INTRODUCTION

Excessive body fat or obesity will soon become the number one killer in the developed world, with the United States leading the way. The National Center for Health Statistics reports that the number of overweight and obese individuals has dramatically increased in recent years. In 1988 to 1994, 22.9% of American adults were obese; by the years 1999-2000 that percentage had shot up to 30.5%, which is almost one in every three adults. The number of individuals considered to be overweight has also ballooned from 55.9 to 64.5%, which are two in every three adults (Flegal et al., 2002). It has also been reported that during the same time frame, the prevalence of obesity in both children and adolescents has increased, especially in non-Hispanic black and Mexican-Americans (Ogden et al., 2002).

Obesity leads to many health problems such as type II diabetes, heart disease, orthopedic problems and certain types of cancers. Billions of dollars are spent each year on treatment and rehabilitation, and as the scope of the obesity epidemic increases, so too will the associated costs. Thanks to widespread publicity about the obesity problem people have started to recognize that increased body weight is extremely detrimental to their health, and some individuals are trying to lose or prevent weight gain.

Body weight is basically determined by the difference between energy intake and energy expenditure. If intake is greater than energy expenditure body weight will increase and if intake is less than expenditure body weight will decrease. In the hope of controlling body weight more and more people have turned to exercise to increase their energy expenditure. According to the Center for Disease Control and Prevention (CDC), from the years 2000 to 2001 the proportion of adults regularly exercising has almost doubled, from 26.2% to 45.4% (The Center for Disease Control and Prevention, 2003).

However, the exact type and amount of exercise that will result in the greatest weight loss is still a matter of debate. Some exercise physiologists, and most of the general public; believe that aerobic exercise helps decrease body weight (Geliebter et al., 1997; Macknigh et al., 2003;

Jakicic et al., 1999). Other physiologists argue that resistance exercise is a better method for controlling weight because it results in higher protein turnover, which can significantly increase basal metabolic rate (BMR) once exercise has been completed (Dolezal et al., 2000; Schuenke et al., 2002; Osterberg et al., 2000). However, to make a tangible effect on total daily energy expenditure and body weight an elevated BMR for at least 24 hours after finishing exercise is needed to help in weight control. Therefore, it is important to know which type of exercise, aerobic or resistance, has a greater effect on post exercise BMR.

Purpose of the Study

The purpose of the present study was to compare the acute effects of similar bouts of continuous aerobic, intermittent aerobic, and resistance exercise on post exercise BMR.

Research Hypothesis

The research hypothesis was that a bout of resistance exercise would have a greater effect on BMR compared to bouts of continuous and intermittent aerobic exercise that was matched for calorie expenditure (kcal) and rate of oxygen consumption. It has been suggested that the energy needed to recover from a resistance exercise bout is greater than that needed to recover from an aerobic exercise bout because resistance exercise produces more protein turnover and protein synthesis (Dolezal et al., 2000; Melby et al., 1993; Thomas et al., 1994).

Assumptions

The following assumptions for this study included:

1. All laboratory equipment yielded accurate measurements over the course of repeated testing.

2. Subjects followed instructions given to them regarding the maintenance of current lifestyle (e.g., diet and daily physical activities) outside of the prescribed program.

Delimitations

The delimitations for this study included:

1. Ten moderately active healthy male college students between the ages of 18-35 years were recruited from Florida State University.
2. Subjects must be healthy, and not have any underlying diseases or medical conditions that would prevent them from performing exercise testing.
3. Subjects must not be taking nutritional supplements, protein supplements, or weight control supplements.
4. During the study the subjects could not change their diet in any way or start any additional exercise programs outside the laboratory.
4. Subjects had their 12-hour post exercise VO_2 and Basal Metabolic Rate (BMR) measured on four different occasions over a four-week period. The four sessions included a control measurement of BMR, measurement of 12-hour post exercise VO_2 and BMR approximately 21 hours after a resistance exercise bout, a continuous aerobic exercise bout, and an intermittent aerobic bout. Each exercise bout was designed to produce similar energy expenditures (kcal) and rate of oxygen consumption with exercise duration approximating 45 minutes.

Limitations

The major limiting factors of this study included:

1. When dealing with human subjects it is often very hard to choose a representative sample from the universe of interest. Subjects were recruited from the Tallahassee, FL area. Subjects were from a moderately active population. The subjects of this study were volunteers and therefore were highly motivated and looking for exercise benefits. For these reasons the volunteers from this study might not be a true representation of the entire population.

2. Bias also existed in this sample. There was geographical bias due to subjects being only from the Tallahassee, FL area. Increase in motivation might have also lead to bias in this study. Since

only men were being used in this study we could not generalize results to women.

3. Since subjects were healthy and were highly motivated, the response variables might be higher than one would normally expect if an individual could have been randomly chosen from the population. Conclusions from this study must take into account the type of individual agreeing to participate in the study and living in this particular area.

4. Diet, sleep and other out-of-laboratory activities could not be controlled. Subjects were, however, advised to follow a similar diet and activity level during the study.

Definition of Terms

Basal Metabolic Rate -- The minimal rate of energy expenditure necessary to maintain functioning of the physiological systems at rest, measured after a full night's sleep in a laboratory under optimal conditions of quiet, rest and relaxation and after fasting for 12 hours (Scott et al., 2003).

Energy Expenditure – The amount of energy, measured in calories or joules that a person uses (Scott et al., 2003).

Energy Intake – The amount of energy, measured in calories or joules that a person consumes (Scott et al., 2003).

Excess Post-exercise Oxygen Consumption (EPOC) – An increase in oxygen consumption above resting levels in the period after exercise (Gaesser & Broooks. 1984).

Fat Free Mass (FFM) -- Another term for lean body mass. FFM refers to muscle, bones, organs, and connective tissue (Scott et al., 2003).

Maximal Aerobic Capacity or Oxygen Consumption (VO_2max) – The maximal capacity for oxygen consumption by the body during maximal exertion (Brooks et al., 1999).

Resting Metabolic Rate (RMR) -- The minimal rate of energy expenditure necessary to maintain functioning of the physiological systems at rest, measured after a full night sleep at subjects' residences or after being transported to a laboratory in the morning, under optimal conditions of quiet, rest and relaxation after fasting for 12 hours (Scott et al., 2003).

Thermic Effect of Activity -- The additional energy expended above RMR and thermic effect of food due to physical activities, including shivering as well as purposeful physical exercise (Scott et al., 2003).

Total Daily Energy Expenditure – The total amount of energy that a person spends in a 24-hour period (Scott et al., 2003).

Thermic Effect of Food – The energy expended in the process of digesting and absorbing food that is consumed (Scott et al., 2003).

One Repetition Maximum (1-RM) – A maximal amount of weight that can be lifted one time through the full range of motion (Scott et al., 2003).

CHAPTER 2
LITERATURE REVIEW

To be able to work out the best exercise for controlling weight, we must first understand how our bodies store energy, and then how they use that energy. This literature review will therefore start with an explanation of substrate utilization of how our bodies utilize their energy storage. Our bodies mainly produce energy by using either carbohydrates or fats. How much carbohydrate or fat is used depends on several factors, all of which will be explained in detail. The second section of the review will explain about total daily energy expenditure (TDEE), the energy the body uses in a 24-hour period. TDEE can be divided into 3 parts: the thermic effect of activity, which is the energy spent during voluntary physical activities; the thermic effect of food, which is the energy used during the digestion and absorption of food; and the basal metabolic rate, which is the energy used for sustaining life. Of these three factors, basal metabolic rate (BMR) is the largest portion of our TDEE, accounting for roughly 60-70% of the TDEE in sedentary people. So anything that affects BMR can significantly affect TDEE. The literature review will therefore focus on factors that effect BMR. Among the mechanisms that influence BMR, fat free mass (FFM) and the acute effect of exercise have the greatest impact. FFM has been shown to explain 80-85% of the between-subject variation in BMR and TDEE. The acute effect of exercise not only increases metabolism rate during exercise but can also affect BMR after exercise has been completed; this phenomenon is called Excess Post Exercise Oxygen Consumption (EPOC). In some cases EPOC can last longer than 24 hours. Recently, many exercise physiologists have become interested in the mechanisms of EPOC, in the factors that affect it, and in the possibility that EPOC can significantly increase TDEE, certainly by enough to have effect on body weight. So the last section of this literature review will present recent studies about the factors that affect EPOC, summarize the studies that report EPOC lasting for longer than 8 hours, and present studies that compare the effect of resistance exercise and aerobic exercise on EPOC.

Substrate Utilization

Our bodies use carbohydrate, fat and protein to produce energy. However, in normal conditions carbohydrate and fat are our main energy sources, with protein contributing just a small amount of the total energy. In sedentary individuals, fat is the predominant fuel source for exercise intensities below 50-65% of maximal oxygen consumption (VO_2max). For exercise with an intensity of more than 50% to 65% of VO_2 max carbohydrate becomes the predominant fuel source (Hultman et al., 1995; Wolfe, 1998; Sidossis et al., 1997). Factors that influence substrate utilization during exercise are: exercise intensity; exercise duration, fuel availability, training status, and environmental conditions.

Exercise intensity affects the rate of lipid oxidation by limiting the availability of fatty acids into the circulation and into the mitochondria. At rest, free fatty acids (FFA) meet most of the body's energy requirements. However, when exercise begins and exercise intensity increases, the rate of lipolysis does not increase proportionally with that of intensity. In sedentary individuals, fatty acid oxidation and the amount of available fatty acids is roughly equal to or below the exercise intensity of 65% of VO_2max (Wolfe, 1998). The possible mechanism for is that lactic acid formation during high intensity exercise inhibits lipolysis from adipocytes (Brooks et al., 1999) thereby limiting the availability of FFA.

During long-duration low-intensity exercise, the body gradually increases its reliance on fat as a substrate. The rate of fat metabolism during long-duration low-intensity exercise is mainly controlled by the lipase enzyme activity. During prolonged low-intensity exercise, blood epinephrine levels increase and blood insulin levels decrease both of which cause an increase in lipase activity and promote lipolysis.

Since lipid availability is one of the determinants of the rate of lipid oxidation during exercise, conditions that increase FFA availability such as a high fat diet or lipid infusion can increase lipid oxidation (Wolfe, 1998; Romijn et al. 1995).

Endurance training increases fatty acid oxidation during exercise at any given absolute intensity. The possible mechanisms for this are: suppressing sympathetic secretion; decreasing lactate formation; increasing lactate clearance (Brook et al., 1999); and increasing the rate of the long chain fatty acids' entry into the mitochondria (Sidossis et al., 1998).

The effect of environmental conditions on substrate utilization can be explained using Brook's crossover concept. At rest our bodies predominantly utilize lipids for energy

metabolism. During exercise, when exercise intensity increases, the point where fat changes from the predominant fuel source to carbohydrate is called the cross over point. In untrained individuals this occurs at approximately 50-65% of VO_2max (Brooks et al., 1999). Increased sympathetic activity pushes the cross over point to the left, meaning that more carbohydrates will be used as fuel at any given exercise intensity. Exercise in hot or extremely cold environments will also increase sympathetic activity altering the cross over point. Therefore, under hot or extremely cold conditions more carbohydrates will be used as a fuel source compared to when exercise is performed in a thermo-neutral environment (Brooks et al., 1999).

In summary, the regulation of the use of substrates during exercise is complex and depends on several factors. Carbohydrates are generally used as the major fuel source during high intensity exercise and fats are used mainly in prolonged low intensity exercise. Armed with this basic knowledge about substrate utilization, some people assume that in order to reduce body fat the intensity of exercise must be kept low, thereby burning fat as a main fuel. A key point to consider, though, is that the total rate of energy expenditure, and the absolute amount of fat metabolized, is greater at higher exercise intensities due to a greater use of fat metabolism during recovery. The absolute total energy expenditure is therefore very important and it is misleading to only consider the energy derived from fat during exercise without taking total energy expenditure into account. That being said, the following sections will review the control of and factors influencing TDEE.

Energy Expenditure

Total daily energy expenditure (TDEE) has three components: the thermic effect of activity, which accounts for about 15-30% of TDEE; the thermic effect of food metabolism, about 10% of TDEE; and the basal metabolic rate (BMR), which accounts for about 60-75% of TDEE.

Thermic Effect of Activity

The thermic effect of activity includes energy used for the activities of daily living, and other physical activities such as exercise. The thermic effect of activity is the most variable component of our total energy expenditure, and it has the most potential for increasing TDEE. Clearly, exercise intensity and duration can have the biggest impact on energy expenditure. The energy needed to run 10 miles is greater than that needed to run five miles. Similarly the energy expended for 20 repetitions of a 100 pound bench press, is greater than that needed to bench

press 100 pounds, 10 times. As long as the exercise intensity remains the same then energy expenditure has a linear relationship with work (Hunter et al., 1998). However, when exercise intensity increases the exercise efficiency decreases, causing a greater expenditure of energy. Treuth et al., (1996) studied the effects of exercise intensity on energy expenditure. Eight women performed an exercise bout of the same duration but at different intensities. In this study the subjects performed two types of exercise, an exercise bout at 50% of VO_2max continuously for 60 minutes, or an interval exercise bout at 100% of VO_2max (2-minute cycling, 2-minute recovery) for 60 minutes. Those performing the 100% of VO_2max interval exercise had significantly higher energy expenditure than those performing the 50% of VO_2max exercise (1464 238 vs. 1197 63 kcal; $P<0.01$). Therefore exercising at higher intensities even though duration is similar is associated with greater energy expenditures.

The thermic effect of activity is the component of energy expenditure that is most responsible for the decline in total energy use in today's society, and it is this, which leads to the increased prevalence of obesity. To treat obesity and facilitate weight loss we not only need to exercise regularly, but we also need to make lifestyle changes, such as using stairs instead of elevators.

Thermic Effect of Food

The thermic effect of food is the energy required for the digestion and absorption processes. The thermic effect of food typically reaches maximal levels within one hour after a meal, depending on food type and quantity. The magnitude of the thermic effect of food ranges from 10 to 35% of ingested food energy. For example a meal of pure protein produces a thermic effect of food equaling 25% of the meal's total calories (McArdle et al., 2000). Unlike the thermic effect of activity, the thermic effect of food has less of an effect on TDEE. Therefore, the thermic effect of food is less important than the thermic effect of activity, and BMR, in terms of helping control weight gain. Therefore it will not be discussed further in this review.

Basal Metabolic Rate

Basal Metabolic Rate (BMR) and Resting Metabolic Rate (RMR) represent the minimum rate of energy expenditure for sustaining life. Both are measured under standardized conditions: at least 12 hours post-prandial; after a restful night's sleep of at least 8 hours; and after a complete rest for 30 minutes. Each is measured in thermoneutral environment (25 1 C). Theoretically RMR and BMR are somewhat interchangeable. However, measuring BMR

requires subjects to sleep over in a facility where their metabolic rates are measured immediately upon awakening. Measuring RMR allows subjects to sleep at their residences; their metabolic rates are then measured following 30 minutes of rest after they have been transported to a testing facility in the morning. The study by Berke et al. (1992) indicated that the pretest environment might influence the rate of energy expenditure. Berke et al. (1992) reported a 7% (4.9 0.13 vs. 4.6 0.13 kJ/min; P<0.01) higher rate of energy expenditure in the same subjects when measured on an outpatient basis (RMR) compared to when they slept overnight in the hospital (BMR). Thus care needs to be taken when trying to compare data across studies using different measurement protocols.

For sedentary people, BMR is the largest part of TDEE and therefore even a minor change in it might have a significant effect on TDEE, and an eventual effect on body weight. The following sections will discuss those factors that may have an influence on BMR; fat free mass (FFM); age; gender; menstrual cycle; genetics; energy balance; exercise training and acute effect of exercise.

Factors That Effect Basal Metabolic Rate

Free Fat Mass

FFM has been shown to explain 80-85% of the between-subject variation in TDEE and BMR (Ravussin et al., 1986, 1992; Illner et al., 2000). Ravussin et al. (1992) studied the relationship between TDEE and FFM in 177 subjects and found that FFM accounted for approximately 80% of the variance amongst subjects. Illner et al. (2000) studied the relationship between RMR and FFM in 26 healthy non-obese adults (13 males, 13 females). Body composition analyses were performed by the combined use of dual-energy X-ray absorptiometry (DEXA), magnetic resonance imaging (MRI), bioelectrical impedance analysis (BIA), and anthropometrics. In females, measurements of RMR and body composition were performed in the follicular phase of the menstrual cycle. RMR was significantly associated with FFM_{BIA} (r = 0.92), $muscle\ mass_{DEXA}$ (r = 0.89), and the $sum\ of\ organs_{MRI}$ (r = 0.90). In a multiple stepwise regression analysis, FFM_{BIA} alone explained 85% of the variance in RMR.

Smith et al. (1997) studied the differences in RMR among subjects (34 women) who had different levels of fitness (VO_2max). The analysis of covariance of RMR (kJ/h) with FFM as the covariate showed no significant difference (P = 0.56) between the high and low-fitness groups, while FFM accounted for most of the differences in RMR between subjects of varying VO_2max

values (Smith et al., 1997). Since the FFM is a major component in RMR, the addition of resistance weight training program to an exercise program for obesity might enhance body composition changes and weight loss.

Age

BMR decreases by approximately 1-2% per decade and this decrease could be explained by a corresponding decrease in FFM (Tzankoff et al., 1977; Calloway et al., 1980; Keys, 1973). However, there is evidence that other factors might also contribute to a decrease in BMR with aging, such as levels of physical activity, hormones, and energy intake. Vaughan et al. (1991) compared energy expenditure in elderly (17 male, 21 female; 71 6 years) and young (33 male, 31 female; 24 4 years) subjects. RMR was found to be lower in the elderly subjects compared to young subjects (6472 507 vs. 6819 1042 kJ/day; $P < 0.01$), after differences in FFM, fat mass, and sex were adjusted. Elderly subjects also had lower energy intake (8041 1231 vs. 9029 1206 kJ/day; $P<0.001$) and spontaneous physical activity (648 35 vs. 756 44 kJ/day; $P<0.001$) than younger subjects. The authors suggested that the decrease in RMR might have come from a decrease in spontaneous physical activity and/or a decrease in energy intake. Therefore, it is important to encourage elderly people to undertake regular physical activity to maintain higher levels of energy expenditure, and to prevent decreases in lean body mass and increases in adiposity.

Gender

There were two studies conducted in a large number of subjects that found the BMR in men to be higher than that in women. One study by Ferraro et al. (1992) compared RMR in 121 women and 114 men, and another study by Arciero et al. (1993) compared TDEE in194 women and 328 men. The results from the study by Arciero et al. (1993) found that, after adjustment for body composition, age and activity levels, the RMR in women was approximately 3% or 50 kcal per day lower than the RMR in men. The TDEE in the study by Ferraro et al. (1992) was approximately 5-10% or about 100 kcal per day lower in women. The mechanisms, as proposed by both sets of authors, for the higher TDEE in men may be due to increases in cell membrane permeability for Na+ and K+, which they thought may be due to the effects of testosterone, leading to a higher Na+ and K+ pump activity causing men to have higher TDEE. The role of testosterone as a modulator of energy balance has been demonstrated in animals. BMR has been

reported to be 13-27% higher in rams compared with their castrated male counterparts (Ferraro et al., 1992). The previous two mentioned studies did not focus on identifying mechanisms by which females have lower metabolic rate than males, and androgen status is potentially an important point for future investigations.

Menstrual Cycle

Well-controlled studies by Solomon et al. (1982) and Bisdee et al. (1989) have demonstrated cyclical changes in women's BMR. Six women in the study by Solomon et al. and eight women in the study by Bisdee et al. lived in a metabolic unit and were controlled for both energy intake and physical activity throughout the test period. Both studies found BMR to be the lowest approximately one week before ovulation and the highest before the menstrual period (6024 351 vs. 6643 817 kJ/d; late follicular vs. late luteal; $P<0.001$). The authors concluded that the change was mainly due to the cyclical nature of progesterone.

Genetics

It is widely believed that obesity is inherited. The data suggest that a genetically determined low metabolic rate is a major risk factor for weight gain in humans. Roberts et al. (1988) studied infants of six lean and 12 overweight mothers, recruited soon after the mothers had given birth. TDEE was measured with a doubly labeled water method over a period of seven days, when the infants were three months of age. TDEE at three months of age was 20.7% lower in the infants who became overweight than in the other infants. This difference could account for differences in weight gain between the two groups of infants. These data suggest that reduced energy expenditure is an important factor in the rapid weight gain in infants born to overweight mothers. Griffiths et al. (1990) studied children of obese and normal-weight parents. The authors found that parental obesity predicted an earlier decline in RMR/kg of body weight. After accounting for the direct effect of genetics on BMR through body composition, body-size and sex (which is approximately 70% of variance in BMR), several studies have found that as much as 40% of the remaining variance in BMR could still be related to genetics (Bogardus et al., 1986; Bouchard et al., 1989, 1993). This can be partly be explained by a genotype-environment interaction phenomenon, the sensitivity to environmental conditions or lifestyle changes (Sorensen et al.1989; Beunen et al., 1999).

Energy Balance

The following studies demonstrated that the state of energy balance has an effect on

BMR. In a study by Kreitzman et al., (1992), eleven healthy female Caucasians aged 34-62 years, weighing 64.8-108.3 kg (body mass index, BMI 22-43 kg/m^2) were recruited for this study. All subjects were put on a very low calorie diet (405 kcal/day) for 11 weeks. There was a significant weight loss (16.2 2.4kg) accompanied by a significant decrease in RMR in these women (5883 732 vs. 5117 582 kJ/d; P<0.01; Kreitzman et al., 1992). In another study, Leibel et al., (1995) demonstrated that TDEE was closely related to energy balance status. Eighteen obese subjects were recruited for this study. The subjects had their TDEE measured at their baseline body weights, after losing 10 to 20% of their body weights during the period of negative energy balance, and after gaining 10% during the period of positive energy balance. The caloric intake was adjusted until the body weight was stable for at least 14 days before measuring TDEE. TDEE increased significantly with weight gain and decreased significantly with weight loss (59 6, 50 9, 42 5, 39 3kcal/kg of FFM per day, 10% weight gain, normal weight, 10% weight loss and 20% weight loss, respectively; P<0.05). These compensatory changes may account for the poor long-term efficacy of weight loss treatment for obesity.

Interestingly, many studies have found that exercise training counteracts the dietary induced decrease of RMR (Lennon et al., 1985; Van dale et al., 1989; Mole et al., 1989; Frey-Hewitt et al., 1990; Lemons et al., 1989; Hunter et al., 1998). In a study by Van dale et al., (1989) 20 women were divided into a diet only and an exercise-diet group (1 hour a day, 4 days a week at 60% of VO_2max) during a 14-week period of caloric restriction (840 kcal/day). Although RMR per unit of FFM decreased in both the diet only group (1.30 0.03 vs. 1.08 0.07 kcal/kgFFM/min; P<0.05) and the exercise-diet group (1.41 0.14 vs. 1.25 0.06 kcal/kgFFM/min; P<0.05), RMR per FFM in the exercise-diet group did not decrease by as much as it did in the diet only group. In a study by Mole et al., (1989) five obese subjects had a caloric restriction of 500 kcal per day for four weeks. The subjects remained sedentary during the first two weeks and then underwent 30 minutes of 60% of VO_2max exercise daily for the last two weeks. After the first two weeks, RMR decreased significantly (P<0.01) by 12%, from 12.7 0.25 to 11.1 0.25 ml /min per unit of body weight. In the second period, after the two weeks of exercise the RMR returned to its baseline level.

A long-term study by Frey-Hewitt et al., (1990), demonstrated a decrease in RMR that accompanied weight loss, when restricting caloric intake. One hundred and twenty one

overweight sedentary men (age 30-59 years) were randomly assigned to a control, an energy restriction or an exercise group. After one year both the diet and exercise groups had significantly decreased their body weight (-6.68 3.94 vs. –4.10 3.74 kg diet vs. exercise; P<0.01) and fat mass (-5.52 4.24 vs. –3.65 3.52 kg diet vs. exercise group; P<0.01). However, the diet group had a significant decline in RMR (-6.21 1.49 kcal/hour; P<0.01) and RMR per unit of FFM (-0.07 0.02 kcal/kgFFM/hour; P<0.05) while the exercise group showed no significant change in RMR (-0.95 1.34 kcal/hour) or RMR per unit of FFM (-0.01 0.02 kcal/kgFFM/hour).

A study in resistance training also demonstrated that exercise might preserve FFM and RMR during a weight loss program. Ryan et al. (1995) studied the effect of a 16-week resistance-training program on RMR during a weight loss program. Fifteen post-menopausal women were recruited for this study. Although body weight (78.7 2.1vs.74.0 2.0 kg; P<0.01), fat mass (33.3 1.9 vs.28.2 1.7 kg; P<0.01) and percent body fat (43.0 1.2 vs.38.9 1.3 %; P <0.01) significantly decreased, RMR (1353 50vs1405 43 kcal/day) and RMR per unit of FFM (32.7 1.0 vs.33.6 0.8 kcal/kgFFM/day) did not have significant changes between pre-training and post-training.

Exercise Training

There is evidence that the chronic effect of exercise training helps to increase BMR, or at least helps to prevent a decrease in BMR due to aging. It may do this by increasing or preserving FFM (Vaughan et al., 1991); by increasing the rate of protein turnover (Rennie et al., 1981); by promoting an increase in the sympathetic nervous system due to an increase in catecholamine sensitivity (Lundholm et al., 1986), and/or by increasing levels of catecholamines (Borsheim et al., 1998).

Acute Effect of Exercise

Many recent studies have found that the acute effect of exercise can also significantly affect BMR. There is evidence to suggest that BMR can be elevated for as long as 24 hours after a single bout of exercise (Schuenke et al., 2002, Dolezal et al., 2000, Bielinski et al., 1985). Since BMR is the largest factor in TDEE, a small change, for instance, of 5-10%, might have a significant impact on TDEE and therefore on body weight. Some of the studies reviewed above produced evidence showing that an elevated metabolism after an acute bout of exercise can have

a profound influence on both BMR and TDEE. The rise in BMR from the acute effect of exercise is called "Excess Post-Exercise Oxygen Consumption (EPOC)", a term coined by Gaesser et al., (1984). EPOC obviously has the potential to be a significant factor in weight loss.

Excess Post-Exercise Oxygen Consumption (EPOC)

The increased O_2 consumption during the recovery period after exercise was originally explained by the O_2 debt theory. This hypothesis stated that elevated O_2 consumption during the recovery period from exercise was necessary to repay the O_2 deficit incurred during the exercise. However, with increased knowledge about the biochemical mechanisms behind post-exercise metabolism, Gaesser et al., (1984) were able to coin the term 'excess post exercise oxygen consumption' (EPOC). During recovery EPOC is made up of two components, one fast and one slow. The fast component usually occurs within 10 minutes of finishing exercise. The slow component starts about 10 minutes after finishing exercise and can last for 24 hours or more. Exercise physiologists have been interested in the EPOC mechanisms for years, even though the exact mechanisms that contribute to EPOC are still a matter of debate. The possible mechanisms for the fast component of EPOC include: replenishing the phosphagen system; restoring hemoglobin and myoglobin; and meeting the elevated energy demands from the cardiac and respiratory muscles (Harris et al., 1976; Boutellier et al., 1984; Gaesser et al., 1984). The possible mechanisms for the slow component of EPOC include: the increase in muscle blood flow (Andersen et al., 1985); a redistribution of body fluids (Rostein et al., 1998); lactate removal (Brooks et al., 1999; McArdle et al., 2000); the process of protein synthesis (Welle et al., 1990); resynthesizing glycogen storage (Ivy et al., 1998; Pascoe et al., 1996); the effects of circulating hormones (Borsheim et al., 1998); an increase in body temperature (Gaesser et al., 1984); and lipid oxidation (Trost et al., 1997, Borsheim et al., 1998).

Mechanisms to Explain EPOC

Seventy percent of creatine phosphate is restored in 30 seconds, a process that is completed entirely in 3-5 minutes (Harris et al., 1976). Therefore, resynthesis of the phosphagen system and the restoration of the oxygen concentration in the blood and tissues occur primarily during the fast component (Boutellier et al., 1984). The EPOC volume from rephosphorylation of creatine and ADP during recovery is approximately 10% of the total EPOC after maximal exercise. The amount of oxygen needed for rephosphorylation may not be more than 1.5 liters, once hydrolysis of the high-energy phosphate stored in muscle during exercise has been

completely used (Gaesser et al., 1984).

Blood flow in active muscle can increase during exercise by up to 30 times, from 10 ml/min 100g to more than 300 ml/min 100g (Andersen et al., 1985). Once the exercise has ended, blood flow to the muscle remains elevated for a period of time. The extent of the increase in muscle blood flow during the recovery period is probably controlled by local metabolites, the degree of ion disturbance, and by the amount of muscle glycogen depletion (Bangsbo et al., 1998). This increase in muscle blood flow leads to an increase in energy expenditure.

An increase in hydrostatic pressure and capillary filtration pressure following exercise alters the body's water equilibrium and promotes a shift of plasma from the blood circulatory system. This results in a decrease of plasma volume after exercise. Rostein et al., (1998) studied the effects of high intensity exercise (6 x 1 minute bursts of cycling at 100% of VO_2max) in 10 trained subjects and found that plasma volume was reduced by up to 20% immediately following exercise (Hematocrit: 45.4 2.6% to50.2 2.5%; $P<0.05$; pre-exercise, immediate post-exercise, respectively). This decrease in plasma volume can last for up to 40 minutes (Hematocrit: 45.4 2.6% to 44.4 3.8%; pre-exercise, 40 minutes post-exercise, respectively). The energy needed to re-balance body fluid is clearly a part of EPOC but does not play a major role.

Once exercise has been terminated, lactate can be removed in any of three different ways: 1) by being used in glycogenogenesis at the liver; 2) by being transported to the liver and forming glucose or liver glycogen in the Cori cycle; and/or 3) by oxidizing into other intermediate substrates in the tissue and used as fuel in the Kreb's cycle (Brooks et al., 1999). It was believed that most of the lactate formed in active muscle reconverts to glycogen, this was discovered in early studies on reptiles, but does not occur in mammals. A study in rats found that 75% of lactate is oxidized into other intermediate substrates and used as fuel in the Kreb's cycle while only 25% is synthesized to glycogen (McArdle et al., 2000).

Protein resynthesis in the normal protein turnover process is metabolically expensive and can contribute up to 20% of BMR (Welle et al., 1990). Therefore, the energy used to repair muscle damage after exercise, especially eccentric-type exercise such as high intensity resistance exercise, downhill running, or high intensity sprinting (all of which induce more muscle damage), might have an important role in EPOC. The muscle damage from high intensity aerobic exercise, such as sprinting, might elevate EPOC for up to 24 hours. In a study by Dolezal et al. (2000), nine resistance training subjects (RT) and nine untrained subjects (UT),

who had no prior resistance training experience, performed eight sets of leg presses at 6-RM. The data showed that the RMR of both groups was elevated for 48 hours (RT: 7800 50 vs. 8601.7 353.7; UT: 7720 40 vs. 8930.9 104.4 kJ/day; pre-exercise vs. 48 hours post-exercise; P< 0.05), accompanied by a higher concentration of blood creatine kinase (RT; 80 10 vs. 800 30; UT; 80 10 vs. 1140.3 37.1 U/L; pre-exercise vs. 48 hours post-exercise; P<0.05). The results demonstrated that high intensity resistance training could elicit EPOC for up to 48 hours.

One of the major components of EPOC is the energy needed for glycogenesis from lactate. The pattern of muscle glycogen synthesis is biphasic (similar to the pattern of EPOC), and is composed of a rapid phase during the first hour and a slow phase of up to 5 hours after finishing exercise. The exact mechanism controlling the rate of glycogenesis is still unclear. However, since glucose transportation might be a rate-limiting step, glucose concentration and insulin levels probably play key roles (Ivy et al., 1998). Glucose transportation is a facilitated diffusion process and depends directly on the number of active glucose transporters on the muscle plasma membrane. Glucose transport protein type 4 (GLUT4) is the predominant glucose transport protein in skeletal muscle. It is believed that insulin enhances glycogenesis by increasing transportation of glucose to muscle through the amount of active GLUT4. GLUT4 becomes active by translocating from intracellular into the plasma membrane. Muscle contractions also induce translocation of GLUT4 but via a different pathway. Blood glucose concentration after exercise has a positive correlation to the intensity of the exercise. Therefore, higher blood glucose from higher intensity exercise increases insulin levels, thus enhancing glucose transportation into muscle and glycogenesis. External glucose supplements taken either orally or parentally also increase the glucose blood levels and the rate of glycogenesis. To maximize glycogen resynthesis after exercise, a carbohydrate supplement of at least 1g/kg of body weight should be consumed immediately after finishing exercise (Ivy et al., 1998). The effectiveness of the carbohydrate supplement to the rate of muscle glycogen recovery during the slow phase is directly related to the plasma insulin response to the supplements (Zawadzki et. al, 1992). Insulin secretion inhibition, by the infusion of Somatostatin, does not significantly change the glycogenesis rate during the rapid phase, but completely stops it during the slow phase, leads us to believe that while the rapid phase is not insulin dependant the slow phase is (Price et al., 1996). Glycogen depletion in muscle also plays a role by converting glycogen synthase from inactive D-form to active I-form.

The rate of muscle glycogen synthesis is directly linked to the intensity of the exercise. The rate of muscle glycogen synthesis in short-term high intensity exercise (100% of VO_2 max) is greater than that in prolonged low intensity exercise (70% of VO_2max; 15.1-33.6 mmol/kg/h vs. 1.5-2 mmol/kg/h; Pascoe et al., 1996). Interestingly, resistance exercise, which is theoretically similar to high intensity interval exercise in terms of work/rest protocols, has a lower glycogenesis rate than short-term high intensity exercise (1.9 – 11.1 mmol/kg/h). The lower rate of glycogenesis might be due to the component of eccentric contraction of resistance exercise, as this leads to more muscle damage, which might deter the process of glycogenesis (Pascoe et al., 1996).

During exercise the sympathetic nervous system is activated, resulting in an increased concentration of plasma catecholamines. Catecholamines are potent stimulators of energy metabolism. Catecholamines may have an indirect effect on EPOC in several ways, such as increases in: heart rate; respiration; blood circulation; glycogenolysis; gluconeogenesis; and lipolysis in adipose tissue. The plasma concentration of catecholamines increases linearly with exercise duration and exponentially with the exercise intensity. This relationship is similar to the relationship between EPOC and exercise duration and intensity (Borsheim et al., 1998). There is some evidence that catecholamine levels are higher after intense anaerobic exercise than after prolonged aerobic exercise (Boisseau et al., 2000)

The elevated concentrations of catecholamines probably contribute to EPOC: by elevating mitochondria respiration: norepinephrine causes cell membranes to be more permeable to sodium ion and potassium ion, thus indirectly enhancing Na+-K+ pump. Another effect of catecholamines is an increase in fatty acid oxidation. Fatty acid oxidation is regulated by fatty acid mobilization, which is highly dependent on catecholamines. Interestingly, although there is evidence that fatty acid oxidation is one of the major contributors to EPOC several researches have found that stimulating or inhibiting catecholamines through the adrenergic receptor does not affect EPOC (Borsheim et al., 1998a, 1998b). In 1998, Borsheim et al. conducted two experiments that involved inhibiting and stimulating the adrenergic receptor. In the first experiment, seven healthy young men cycled at approximately 60% of their VO_2max for 90 minutes. Immediately after exercise, the subjects received three interventions: 1. propanolol, a non selective beta-adrenergic receptor antagonist (propanolol); 2. a selective $beta_1$-adrenergic receptor antagonist (atenolol); and 3. a control consisting of saline solution. There were no

differences in the time course or magnitude of EPOC with any of the three interventions (saline: 7.5 1.2 L., atenolol: 9.7 1.3 L. and propanolol 7.8 1.6 L.; P= 0.52). In the second experiment, eight healthy young men exercised with the same protocol as in the first experiment. Immediately after exercise the subjects received isoprenaline, the beta-adrenergic receptor agonist, and saline as a control. Again there was no difference in the time course or magnitude of EPOC (the total EPOC: 10.8 ± 1.8 vs. 8.1 ± 1.8 L.; isoprenaline vs. control; P=0.40).

Growth hormone also may have a role in EPOC, since growth hormone promotes lipolysis, and there is evidence that plasma growth hormone levels increase significantly from resting levels after 40 minutes of exercise. The extent of elevation is directly related to exercise intensity and duration, with less fit individuals having a greater response than those who are fit (Warren et al., 2000). The magnitude of GH release is greater in young women than in young men and is reduced by 4-7 fold in older individuals compared with younger individuals (Wideman et al., 2002, 1999; Zaccaria et al., 1999; Marcell et al., 1999).

No differences in 24-GH release have been reported between continuous exercise and intermittent exercise. The pattern of GH response to acute resistance exercise is similar to acute aerobic exercise, with the same average peak GH concentration of 5-25 µg/L attained during both resistance and aerobic exercise (Nindl et al., 2001, Raastad et al., 2000, Takarada et al., 2000, Kraemer et al., 1999a, Kanaley et al., 1997, 2001, Weltman et al., 1997, Pritzlaff et al., 1999).

The alteration of body temperature plays an important role in the body's metabolic rate, and the increases in tissue temperature and EPOC are very closely associated. A one degree Celsius increase in body temperature elevates BMR by approximately 10%. The enzymatic reaction would be doubled for every 10 degree Celsius increase in body temperature due to the Q10 effect. The probable mechanism being that an increase in body temperature decreases metabolic efficiency; phosphorylation coupling and energy tapping (Gaesser et al., 1984). Hence, higher oxygen consumption would be necessary for a given amount of ATP to be synthesized. The elevated temperature might also cause substrate cycling, which is also referred to as futile cycling (Newsholme 1978; Bahr et al., 1990). Newsholme (1978) proposed that heat generation by substrate cycles might be important as an acute mechanism for maintaining the body temperature in humans in response to a sudden decrease in the environmental temperature. Substrate cycles could also be part of a general biochemical mechanism for maintenance of the

correct body weight; a decrease in the capacity of substrate cycles might be one factor involved in the development of obesity. Substrate cycles would have to operate at only 3-17% of maximal capacity to account for an oxygen uptake of about 1ml O_2/min/kg (Newsholme, 1978).

Since the energy equivalent of O_2 is lower for fats then for carbohydrates, an increase in lipid oxidation after exercise is probably one of the major contributors to EPOC (Trost et al., 1997, Borsheim et al., 1998). Trost et al. (1997) studied the effect of nicotinic acid, a potent inhibitor of FFA mobilization on lipid oxidation and energy expenditure during recovery from exercise. In this study, five trained male cyclists received nicotinic acid prior to, during and after exercise. When the subjects received nicotinic acid their FFA levels were significantly lower than was the case in the control trial, during both the exercise and recovery periods. Nicotinic acid also significantly reduced the magnitude of EPOC when compared to the control trial (5.5 0.71 vs. 3.4 0.61 L; $P<0.01$; Trost et al., 1997). These findings are consistent with the theory that an increased rate of lipid oxidation is responsible for a significant portion of the EPOC. In this study inhibition of FFA mobilization and utilization with nicotinic acid resulted in a significantly lower elevation in postexercise VO_2. Thus, the results of this study support the hypothesis that FFA metabolism during recovery is an important contributing factor to the magnitude of EPOC.

Factors Influencing the Magnitude of EPOC

Exercise intensity is probably the major contributing factor to the magnitude of EPOC. Most researches report a strong positive correlation between exercise intensity and the magnitude of EPOC. Borsheim et al. (1998) proposed the positive curvilinear relationship model between the magnitude of EPOC and the intensity of exercise. Dawson et al. (1996) compared EPOC from three different exercise intensities: high intensity (65% of VO_2max), moderate intensity (55% of VO_2max), and low intensity (45% of VO_2max) in eight healthy young female subjects. All the subjects cycled on a cycle ergometer for 30 minutes during the high intensity exercise protocol. Then, in the moderate and low intensity protocols the subjects exercised until the energy cost matched the energy expended in the high intensity protocol. The gross EPOC was significantly greater in the high intensity exercise group than in those of moderate and low intensities. There was no difference in the magnitude of EPOC between the moderate intensity and the low intensity groups (137.0 6.3*, 116.6 8.7, 107.4 5.8 kJ; high intensity, moderate intensity, low intensity groups, respectively; $P<0.001$).

Frey et al., (1993) compared EPOC between short-term high intensity exercise (HI; 80% of VO_2max) and long-term low intensity exercise (Low; 65% of VO_2max). In both protocols seven untrained subjects exercised until they had expended 300 kcal. The magnitude of EPOC (102.6 15.7 vs. 69.6 10.4 ml/kg), rectal temperature (37.1 0.10 vs. 36.8 0.09 C), and lactate (1.50 0.12 vs. 1.31 0.22 mmol/L) was significantly higher in the HI protocol than in the Low (all significance at $P<0.05$).

There is evidence that EPOC has a linear relationship with exercise duration. However, there might be a threshold of exercise intensity that has to be attained before exercise duration has an effect on EPOC (Borsheim et al., 1998; Gore et al., 1990, Chad et al., 1988, Quinn et al., 1994, Bahr et al., 1987, Sedlock et al., 1989). It has been suggested that the exercise intensity must be above 70% of VO_2max to affect EPOC (Borsheim et al., 1998). Bahr et al. (1987) compared EPOC in six healthy male subjects after they had exercised at 70% of VO_2max for 20, 40 and 80 minutes. The magnitude of the 12-h EPOC had a statistically significant positive linear relationship with the exercise duration ($P<0.02$). The magnitude of 12-h EPOC above control level after 20, 40 and 80 minutes were 5.1 1.2, 6.8 1.7, and 14.4 1.2% respectively.

Quinn et al. (1994) compared EPOC in eight trained female subjects after they had exercised at 70% of VO_2max for 20, 40 and 60 minutes. The three-hour EPOC was significantly higher for the 60-minute exercise (15.2 L) than for the 40-minute exercise (9.8L) and 20-minute exercise (8.0 L; $P<0.01$). Chad et al. (1988) compared EPOC in two male and three female subjects after they had exercised at 70% of VO_2max for 30, 45 and 60 minutes. The net EPOC increased 2.3 and 5.3 fold when exercise duration was increased from 30 minutes to 45 and 60 minutes, respectively (6.78 0.27, 16.00 0.67, 35.96 3.15 L.: the net EPOC for 30, 40 and 60 minutes exercise duration). Gore et al. (1990) compared EPOC in nine men after 20, 50 and 80 minutes at 30%, 50% and 80% of VO_2max. In this study, the authors found no difference in EPOC among the 20-, 50- and 80-minute walks at 30% of VO_2max. For running at 80% of VO_2max, EPOC increased significantly with duration.

Laforgia et al. (1997) compared EPOC between sub-maximal continuous exercise and supra-maximal interval exercise. Eight male middle-distance runners completed two exercise protocols: 1. continuous running for 30 minutes at 70% of VO_2max, and 2. interval running: 20 sets of one minute running at 105% of VO_2 max, with intervening two-minute rest periods. The nine-hour EPOC values in the interval protocol were significantly higher than in the continuous

protocol (15.0 3.3 vs. 6.9 3.8 L; P<0.001). Kaminsky et al. (1990) compared EPOC in six female subjects split between 50 minutes of running at 70% of VO_2max and 2 x 25 minutes of running at 70% of VO_2max. The EPOC in the 50 minutes continuous running, the first 25 minute run and the second 25 minute run were 6, 8, 6 Kcal, respectively. The magnitude of EPOC among the three runs was not different, but the combined EPOC from the two 25 minute runs was higher than that of the 50 minute run (14 vs. 6 kcal; P<0.01).

Training status also affects the magnitude of EPOC and it might also explain the differences in magnitude and duration of EPOC among the various studies. Several studies support the hypothesis that training has the potential to reduce the recovery period (Short et al., 1997, Hagberg et al., 1980, Tomlin et al., 2001), improve lactate removal, enhance the phosphagens resynthesis process (Van dale et al., 1987, 1989) and decrease catecholamine sensitivity (Brooks et al., 1999). When exercising at the same relative level of VO_2max, trained individuals exercise at a higher absolute intensity. Hence, they consume more oxygen and their VO_2 at the start of the recovery periods are higher, which might lead to higher magnitudes of EPOC. However, total recovery time might be the same or shorter due to their faster recovery process. Short et al. (1997) compared EPOC between trained and untrained individuals after they had exercised at the same relative intensity at 70% of VO_2max for 30 minutes. The trained group had a shorter EPOC duration (40 15 vs. 50 14 minute; P<0.05), although neither group showed significant differences in the magnitude of EPOC (67.7 16.3 vs. 67.8 17.9 kJ).

In terms of the implications for weight loss, it appears that an exercise intensity of at least 50% of VO_2max or higher is needed to produce an increase in energy expenditure after exercise that lasts for several hours. However, an elevated RMR for at least 24 hours after finishing exercise is needed to make a tangible impact on TDEE, and body weight. Table 1 summarizes a series of studies evaluating the effects of endurance and resistance training on elevating energy expenditure after exercise has been completed. However, it must be noted that individuals of the general public are unlikely to engage in such long duration aerobic exercise or rigorous resistance exercise used in the studies shown in the table below. Therefore further research is needed using exercise protocols with shorter durations and lower intensities that are more practical for individuals who are beginning exercise programs, trying to lose weight.

Table 2.1 Summary of research on the acute effects of exercise that has increased RMR for eight hours or more

Author(s)	Subject(s)	Exercise Protocol	Result
Bielinski et al. (1985)	10 male subjects, age 21.8 0.3 year, VO_2max (62.5 2.2 ml/kg/min), body fat = 11.9 0.6%	Running on a treadmill for 3 hours at 50% of VO_2max (1.44 0.06 vs. 1.37 0.05) kcal/minute; P<0.05).	4.7% increase in the 24-hour post exercise RMR
Wither et al. (1991)	8 male subjects age 26.0 6.6, VO_2max (65.0 3.5 ml/kg/min) body fat, 10.3 2.2%	Running on a treadmill at 70% of VO_2 max for 164 minutes.	23.7% increase in 8-hour RMR (32.4 L; 154.5kcal)
Osterberg et al. (2000)	7 young female subjects. (Regular exercisers.) age 27.0 1.8 year, body fat = 18.3 1.6%	5 sets of circuit training, comprising 10-15 repetitions of 10 exercises at 12RM, with 2 minutes rest between sets	4.2% increase in the 16 hour post exercise RMR (1419 58 vs. 1479 65 kcal/day; P<0.05)
Dolezal et al. (2000)	9 trained and untrained subjects, age 20.7 2.1 year; body fat = 10.2 1.6%	8 sets of leg presses, with 6 repetitions at 6RM, with 3 minutes rest between sets.	18% increase in the 24-hour RMR, and an 11% increase in the 48-hour RMR (both groups averaged together). The UT group showed a significantly higher RMR than the RT group, both at

Table 2.1 continued

			24-hour (9705.4 204.5 vs. 9209.3 535.3 kJ/day; P<0.05) and 48-hours post exercise (8930.9 104.4 vs.8601.7 353.7 kJ/day; P<0.05).
Schuenke et al. (2002)	7 regularly weight training male subjects, age 23 3 year, body fat 10.4 4.2%	4 sets of circuit training, comprising 8-12 repetitions of 3 exercises at 10 RM, with 2 minutes rest between sets	20% increase in the 48-hour RMR

Comparing the Effect of Endurance Exercise and Resistance Exercise on BMR

As mentioned above, some exercise physiologists have proposed the hypothesis that resistance exercise alone or combined with aerobic exercise is better for controlling weight. There are many researchers trying to prove this hypothesis by comparing both the acute effects of aerobic exercise and resistance exercise on BMR (Burleson et al., 1998) and the combined effect of aerobic training and resistance training on BMR (Broeder et al., 1992; Brett et al., 1998; Geliebter et al., 1997).

Broeder et al., (1992) compared the effects of 12 weeks of endurance training and resistance training in 64 volunteer men aged 18-35 years. Subjects were randomly assigned into three groups: control, resistance training and endurance training. For subjects in resistance training group, each subject performed heavy resistance training with a combination of free weights and Nautilus machines, 4 days a week. The strength training program included the following movements: bench press, parallel dip, behind-neck press, upright rows, triceps press down, leg press, leg extension, leg curl, lateral pulldown, barbell curl, and abdominal crunch. Each subject performed 8-12 repetitions per set and three sets per exercise. Each subject in the endurance-training group ran 4 days a week starting with an intensity of 70% of VO_2max for 40

minutes and gradually increasing to 85% of VO_2max. RMR was measured before and after either the training or control period. Subjects did not perform any exercise training for at least 48 hours before each RMR test to avoid an acute effect of exercise. This study found no statistical difference in RMR between pre and post training for the resistance and endurance training groups (control: 5.53 0.17 vs. 5.48 0.13; resistance: 5.36 0.17 vs. 5.53 0.21; endurance: 5.23 0.13 vs. 5.32 0.13 kJ/min; pre vs. post).

Dolezal et al., (1998) compared the effect of 10 weeks endurance training, resistance training and combined training on 30 healthy male subjects age 20.1 1.6 years. All subjects trained 3 days a week. In the resistance training group, each subject performed 10-15 repetitions per set, 3 sets of each of the following exercises: bench press, lateral pulldown, shoulder press, biceps curl, triceps pushdown, back squats, leg extension, leg curl, clean pulls, incline dumbbell press, leg press, seated row, and upright row. In the endurance-training group, each subject started running at 65% of VO_2max for 25 minutes and gradually increased to 75-85% of VO_2max for 40 minutes. In the combined group, each subject participated in the same endurance and resistance training programs as the other two individual groups with the resistance training always completed first. The subjects' BMR measurements in the resistance training and the combined training groups were significantly increased from pre to post measurements (Resistance training: 7613.3 968.7 vs. 8090.8 951.2*; Combined: 7454.9 964.2 vs. 7801.8 980.6*; Endurance training: 7231.2 554.1 vs. 7029 666.4 kJ/day; pre vs. post; $P< 0.05$). However there was no significant change in subjects' BMR measurements per unit of FFM in all three groups (Resistance training: 4.87 0.19 vs. 5.01 0.26; Combined: 4.88 0.40 vs. 4.53 0.24; Endurance training: 4.62 0.21 vs. 4.53 0.24 kJ/kgFFM/hour).

Comparing aerobic exercise with resistance exercise is problematic due to difficulty in equalizing the amount of energy expenditure between resistance and endurance exercise. The major flaw in the experimental designs of the studies by Broeder et al. (1992), Dolezal et al., (1998) and Geliebter et al., (1997) is that they did not match any exercise parameter between aerobic training protocols and resistance training protocols i.e. amount of kcal spent, exercise intensity or exercise duration. Therefore, it is not surprising that results are mixed, since there are differences in methodology among the different research studies. The study by Burleson et al. in 1998 was the only one that equalized exercise intensity between resistance exercise and

aerobic exercise. However, this study failed to match the total kcal spent. Therefore, to make a fair comparison between resistance exercise and aerobic exercise, it is important to a create protocol that equalizes both the amount of kcal spent and the exercise intensity.

A study by Burleson et al. in 1998 compared the acute effect of resistance exercise and aerobic exercise. In this study, 15 males (22.7±1.6 years; body weight 82.0 14.3 kg; body fat 13.1 7.6 %, VO_2max 3.57 0.61 L/min) performed a 27-minute bout of circuit weight training of exercise at 60% of each subject's 1-RM and a 27-minute bout of treadmill exercise at matched rates of VO_2. In this study the resistance exercise session always preceded the treadmill session, and the sessions were separated by a minimum of 5 days. Subject's expired air was collected continuously and used for calculating an average rate of VO_2 during the 27-minute bout of resistance exercise. The treadmill session consisted of walking or jogging on the treadmill at speed that produced the same level of VO_2 at each subject's average VO_2 during the weight training session (approximately 45% of VO_2max). The appropriate treadmill speed was extrapolated from the results of the maximal treadmill test. Each subject's EPOC was measured at 30, 60 and 90 minutes after exercise. Resistance exercise produced the highest total oxygen consumption during the first 30 minutes after exercise (19.0 vs. 12.7 L; $P < 0.05$). There were no significant differences in VO_2 at 60 and 90 minute after exercise for both sets of exercises. The authors concluded that resistance exercise with the same rate of VO_2 produced higher EPOC than aerobic exercise. However, in this study for the aerobic exercise intervention, subjects ran at low intensity and short duration, only at approximately 45% of their VO_2max for 27 minutes. Therefore, it is not surprising that there were no differences in EPOC after the aerobic exercise session. Another point that needs to be mentioned is that this study did not match the amount of energy expenditure between the resistance exercise session and the aerobic exercise session. Moreover, it is clear that a high intensity intermittent aerobic exercise produces higher EPOC than a low intensity continuous aerobic exercise with the same energy expenditure (Zoladz et al., 1998; Borsheim et al., 1998; Dawson et. al, 1996). Therefore, it would be interesting to compare the acute effects of a resistance exercise with a high intensity intermittent aerobic exercise, matching both a rate of VO_2 and an amount of energy expenditure with a longer exercise duration and higher exercise intensity.

As mentioned earlier, the epidemiology data demonstrate an increasing prevalence of obesity. One of the reasons for this increase in obesity may be due to the decrease in TDEE in

United States and other developed countries. Energy expenditure related to physical activity is most likely responsible for the recent decline in TDEE. The energy expenditure associated with physical activity is the most variable component of the TDEE and it has the greatest potential for increasing TDEE and thereby reducing body weight. In early years, exercise protocols for weight loss programs were focused on low intensity exercise. This was based on the knowledge that fats are mainly used in prolonged low intensity exercise. However, high intensity exercise and/or resistance exercise may add additional benefits to exercise programs because of the higher absolute energy spent during and after exercise. High intensity exercise and/or resistance training may also increase BMR through increases in FFM. Theoretically, if energy expenditure after exercise (EPOC) is increased by 10%, which would be equal to approximately 200 kcal/day, this number represents more than half of the normal energy used by an untrained individual to exercise for 45 minutes at a moderate intensity. Therefore, energy expenditure from EPOC alone could translate to a weight loss of one and a half pounds per month. This could have important implications for the maintenance of body weight or weight loss in overweight and obese individuals.

CHAPTER 3
METHODOLOGY

Subjects

Ten moderately active, non-smoking, male college students between the ages of 18-35 years were recruited for this study through flyers (Appendix A) posted around the Florida State University. Subjects were healthy and did not have any underlying diseases or medical conditions that would prevent them from performing exercise testing. Subjects were not taking any nutritional supplements or weight control pills. All participants had the testing procedures and risks explained to them and then signed informed consents (Appendix B) that were approved by the Institutional Review Board at the Florida State University (Appendix C). All subjects were asked to complete demographic, medical history, family history, nutritional, smoking and physical activity questionnaires before participating in the study (Appendix D).

Instrumentation

Height and weight were measured with subjects wearing shorts and t-shirts. Body mass index (BMI: kg/m^2) was calculated from body weight using a Seca scale (nearest 0.1 kg; Seca Model 707; Columbia, MD) and height using a stadiometer (nearest 0.1 cm; Medart, St. Louis, MO). Body Fat was assessed using the sum of three skinfolds, which were measured by the Lange skinfold calipers (Cambridge Scientific Industries, Inc., Cambridge, MD).

Gas exchange and ventilatory parameters were measured by a metabolic cart system (Truemax 2400 Metabolic Measurement System, Consentius Tehcnologies, Sandy, UT). Ventilatory parameters were used to calculate VO_2max, BMR, baseline VO_2, 12 hour post exercise VO_2 and rate of exercise VO_2 and total kcal spent. Prior to testing the metabolic system was calibrated according to manufacturer's recommendations. First, a gas calibration was performed using a gas mixture of known concentrations of O_2 and CO_2 (16%O_2; 4%CO_2, Scott Medical Products, Plumsteadville, PA). Next, the metabolic system was flow calibrated with a 3L calibration syringe (no.5530, Hans Rudolph, Inc., Kansas City, MO). Environmental temperature, humidity and barometric pressure were measured using an indoor climate monitor

(Perception II TM, Davis Instruments, Hayward, CA) and data were inputted into the metabolic cart system for internal adjustment of data. A mouthpiece was connected to a plastic hose (no.1003, Vacumed, Ventura, CA) and was used to collect expired air from the subjects and deliver it to the metabolic cart system for analysis during the three exercise sessions. A ventilation mask (Survivair BLUE 1, Comasec Inc., Enfield CT) attached to a nine-foot breathing tube (no. 112263 2700B and 666021, Hans Rudolph, Inc., Kansas City, MO) was used to collect expired air and deliver it to the metabolic cart system during one baseline VO_2 and the four BMR and three 12-hour post exercise VO_2 measurements.

One repetition maximal (1-RM) test and all resistance exercise sessions were performed on a Smith weight training machine (The Sport Authority, Eagelwood, CO). The maximal aerobic exercise test and all aerobic exercise sessions were performed on a cycle ergometer (Monark 818 E Ergomedic, Varberg, Sweden).

Body temperature. Body temperature was measured using an oral thermometer (TSR-616S, Samsung America Inc., Ledgewood, NJ) before each of the metabolic measurements.

Data Collection

Body Composition Measurement

Subject's body fat was assessed using the Jackson and Pollock (1985) three-site formula (chest, abdomen, thigh) and Siri equation (1956) for estimating body fat percentage. Measurement was performed using procedures outlined in the *ACSM's Guidelines for Exercise Testing and Prescription (2000)*. Lange skinfold calipers (Cambridge Scientific Industries, Inc., Cambridge, MD) were used for this procedure; duplicate measures were made at each site unless they were not within 1 mm whereas an additional measurement were made

Maximal Aerobic Exercise Test.

Subjects' maximal aerobic capacity was determined by a graded exercise test to exhaustion on the cycle ergometer. Heart rate was monitored using a polar heart rate monitor (Polar CIC Inc., Port Washington, NY). The test began with a 5-min warm-up period, followed by an increase of resistance of 0.5 kp every two minutes. Subjects maintained their speed at 50 rpm. VO_2max was defined as the point at which three out of four criteria were met 1) plateau of the oxygen consumption (< 2.0 ml/kg/min) with an increase in exercise intensity 2) attainment of

a respiratory exchange ratio of 1.10 or greater 3) attainment of heart rate within ± 10 beat/min or age predicted maximal heart rate 4) and exhaustion or an RPE of 18 or higher (Howley et al., 1995). If the subjects did not meet the three out of four criteria listed above the test was repeated.

One Repetition Maximum Test

For the 1-RM test all subjects had practice sessions on a separate day using a light resistance to learn proper techniques and form on the equipment. The following exercises were used: vertical butterfly, squat, toe raises, lateral pulldown, and triceps press down. On the 1-RM test day, subjects warmed up by performing the exercise several times at no resistance. The 1-RM was determined by having the subject perform each of the exercises with a resistance that produced muscle fatigue in one lift. Subjects then returned again after 72 hours to verify their maximal 1-RMs.

Dietary Record.

Each subject kept a dietary record of the foods that were consumed 72 hours prior to each BMR test. The subjects were asked to consume foods they normally eat and to replicate the 72-hour food intake for all four BMR measurements. Subjects were given copies of their original food diary (Appendix E) that they completed before their control BMR measurement.

Baseline and 12-hour Post Exercise VO_2

Baseline and three12-hour post exercise VO_2 were determined by indirect calorimetry using the metabolic cart machine. Subjects reported to the exercise physiology laboratory at 9:00 pm after fasting for three hours. They were asked not to eat anything after 6.00pm and drink only water. Subjects rested in the supine position for 30 minutes before having their metabolic rate measured using the metabolic cart machine through the ventilation mask. The ambient room temperature was maintained at 24 1 ^{o} Celsius, the room was darkened, and noise was kept at a minimum during the testing. After the 30 minutes of rest subjects put on the ventilation mask and ventilatory gases were collected over an additional 30-minute period. The subject's baseline and three post exercise VO_2 were the average oxygen uptake over the 30-minute period.

Baseline and 21-hour Post Exercise Basal Metabolic Rate (BMR)

Basal metabolic rate was determined on four occasions by indirect calorimetry using the metabolic cart machine. Subjects slept overnight in the laboratory from 10:00 pm to 6:00 am. Subjects were informed not to eat anything after 6:00 pm and drink only water. After waking up, subjects were instructed to minimize physical activity, by dressing slowly and not taking a shower. Subjects walked to the testing area and rested in the supine position for 30 minutes before having their BMR measured using the metabolic cart machine through the ventilation mask. The ambient room temperature was maintained at 24 1 ^{o} Celsius, the room was darkened, and noise was kept at a minimum during the testing. After the 30 minutes of rest subjects put on the ventilation mask and ventilatory gases were collected over an additional 30-minute period. The subject's BMR was the average oxygen uptake over the 30-minute period.

Research Protocol

At the preliminary meeting, subjects completed a demographics form and an informed consent. Subjects had the procedures of the study explained to them and how to complete their dietary records. Subjects were informed to record their food intake for a 3-day period prior to their baseline BMR measurements. Subjects were asked to eat the same foods in like amounts at the same time of day for every 3-day period prior to all three post exercise BMR measurements. Subjects then had a resistance exercise practice session using a light resistance to learn proper techniques and form on the equipment.

Three exercise sessions of resistance exercise, continuous aerobic exercise and intermittent aerobic exercise and one control session were implemented. Post exercise VO_2 was measured at the control session and at approximately 12 hour and 21 hours (BMR) post exercise sessions. All subjects participated in the control session first then the resistance exercise, followed by the continuous aerobic exercise, and then the intermittent aerobic exercise session (See Figure 1 for research protocol).

Control Session. Subjects reported to the laboratory at 9:00 pm the night before their testing date. They turned in their 3-day dietary food log. They had their baseline VO_2 and body temperature measured. Then they stayed overnight in the laboratory and the next morning they

had their baseline BMR, body temperature, height, body weight, body composition, maximal aerobic exercise test and their 1-RM strength measured. Subjects then returned again after 72 hours to verify their maximal 1-RMs.

Resistance Exercise Session. Prior to the resistance training session subjects were given their 3-day dietary food log and were asked to replicate their food intake 2-days prior to the resistance exercise session and the day of the session. Subjects then reported to the laboratory at 9:00 am and performed a bout of resistance exercise consisting of vertical butterflys, squats, toe raises, lateral pulldowns and triceps press downs. All exercises were performed at approximately 50-60% of subjects'1-RM. In each set of exercise, subjects performed as many as repetitions as possible, followed by 60 seconds of rest. Exercise duration for the resistance exercise session was fixed at 45 minutes. During the 45-minute bout of resistance exercise, subject's expired air was collected continuously. The metabolic cart machine analyzed expired air breath by breath and reported gas parameter data with 1-minute averaging. The gas parameters were used to calculate total kcal spent and the average rate of VO_2. Subjects reported that evening to the laboratory at 9:00 pm to have their 12-hour post exercise VO_2 and body temperature measured. They stayed overnight and had their BMR and body temperature measured the following morning at approximately 6:00 am.

Continuous Aerobic Exercise Session. Subjects reported to the laboratory at 9.00am, again after replicating their dietary logs, and cycled on the cycle ergometer continuously at intensity approximately 40% of VO_2max. Subject's expired air was collected continuously. The metabolic cart machine analyzed expired air breath by breath and report gas parameter data with 1-minute averaging. The gas parameters were used to calculate total kcal spent and average rate of VO_2. Subjects cycled at the work load that produces the same average rate of VO_2 at each subject's average rate of VO_2 during the resistance exercise session. The beginning cycling work load was extrapolated from the results of the maximal aerobic exercise test (see Table 3.1 for examples of calculation). However, during the test, the work load may have been adjusted to elicit the same average rate of VO_2 at each subject's average rate of VO_2 during the resistance exercise session. Subjects cycled until they expended the same total kcal measured during the resistance exercise session (which took approximately 40-50 minutes). Subjects reported again to the laboratory at 9.00 pm to had their 12-hour post exercise VO_2 measured and stayed overnight in the laboratory and then had their BMR measured the following morning.

Intermittent Aerobic Exercise Session. Subjects reported to the laboratory at 9:00 am and cycled on the cycle ergometer alternatively between high and low intensity exercise. Again subjects had replicated their 3-day dietary records. Each round of the intermittent aerobic exercise session consisted of a high intensity interval between 90%-100% of VO_2max and a low intensity interval at 20-30% of VO_2max (zero kp or no load). For the high intensity interval, subjects cycled for 30 seconds and for the low intensity interval, subjects cycled until the average rate of VO_2 in that interval matched the average rate of VO_2 during the resistance exercise session (the time interval was approximately 120-180 seconds). See Tables 3.1 through 3.4 for examples of calculations. Subject's expired air was collected continuously. The metabolic cart machine analyzed expired air breath by breath and report gas parameter data with 1-minute averaging. The gas parameters were used to calculate total kcal spent and average rate of VO_2. Subjects cycled until they expended the same amount of kcal measured during the resistance exercise session (which took approximately 40-50 minutes). Subjects reported again to the laboratory at 9:00 pm to have their 12-hour post exercise VO_2 and body temperature measured and stayed overnight in the laboratory and were measured for BMR and body temperature the following morning.

Each exercise session was separated by at least seven days to avoid a residual effect of the previous bout of exercise. Subjects were informed to avoid any vigorous physical activity at least 72 hours prior to each session. The subjects were asked to consume foods they normally ate and use the dietary food log to help replicate the 72-hour food intake for all four BMR measurements.

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	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
			Control Session	Break 7 days ---->			
	<---------- Dietary record ---------->						
6AM				BMR, body temperature, body composition, VO2max, 1-RM			
10AM							
10PM			Baseline VO2, body temperature				

	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
			Resistance exercise session	Break 7 days ---->			
	<---------- Replicate dietary Record ---------->						
6AM				BMR, body temperature			
10AM			Exercise				
10PM			12 Hour EPOC, body temperature				

	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21
			Continuous aerobic session	Break 7 days ---->			
	<---------- Replicate dietary Record ---------->						
6AM				BMR, body temperature			
10AM			Exercise				
10PM			12 Hour EPOC, body temperature				

	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27	Day 28
			Intermittent aerobic session				
	<---------- Replicate dietary Record ---------->						
6AM				BMR, body temperature			
10AM			Exercise				
10PM			12 Hour EPOC, body temperature				

Figure 1. Research Protocol

Table 3.1 Simulation of energy expenditure report for the VO_2 max test

Time (minute)	VO_2 (ml/kg/min)	Cycling work load (kp)	Ratings of Perceived Exertion
1	10.0	0.0	3
2	13.0	0.5	5
3	15.0	1.0	7
4	20.0	1.5	10
5	25.0	2.0	12
6	31.0	2.5	14
7	35.0	3.0	16
8	35.0	3.5	18

From this simulated data, the beginning cycling work load was used to try and elicit a VO_2 close to the average rate of VO_2 measured during the resistance session (17.2 ml/kg/min) should be 1.25 kp. However, during the exercise session, the work load was adjusted.

Table 3.2 Simulation of energy expenditure for the resistance exercise session for only seven minutes

Time (minute)	VO_2 (ml/kg/min)	Accumulate VO_2 (L)	Accumulate kcal (kcal)
1	25.0	2	7
2	15.0	3	11
3	15.0	4	15
4	24.0	6	22
5	14.0	7	27
6	13.0	8	32
7	15.0	9	37

Average VO_2 = 17.2 ml/kg/min

Total kcal spent 37 kcal

Table 3.3 Simulation of energy expenditure for the continuous aerobic session for only eight minutes

Time (minute)	VO_2 (ml/kg/min)	Accumulate VO_2 (L)	Accumulate kcal (kcal)
1	17.2	1	5
2	17.2	2	10
3	17.2	4	15
4	17.2	5	20
5	17.2	6	25
6	17.2	8	30
7	17.2	9	35
8	17.2	10	40*Stop exercise

Exercise intensity was kept at a work load that produced a VO_2 equal to the average VO_2 measured during the resistance training session. Exercise was stopped once the accumulate kcal reached or exceeded the accumulate kcal from resistance exercise session.

Table 3.4 Simulation of energy expenditure for the intermittent aerobic session for only seven minutes

Time (minute)	VO_2 (ml/kg/min)	Accumulate VO_2 (L)	Accumulate kcal (kcal)
1[a]	32.0	3 (1)	10
2[b]	12.0	4 (2)	14
3	13.0	5 (4)	18
4	11.0	5 (5)[c]	22
5[d]	32.0	8 (6)	32
6	13.0	9 (8)	34
7	12.0	10 (9)	38* stop exercise

[a] Start with the high intensity interval for 30 seconds (90-100%) of VO_2max

[b] The low intensity interval had subjects cycled with no load

[c] Subjects cycled at no load until the accumulate VO_2 caught up with the accumulate VO_2 data from continuous aerobic session

[d] Start next round of the high intensity interval

Statistical Analysis

Statistical analysis was performed using SPSS for Windows version 11.0 (SPSS Inc., Chicago, IL). Sample size estimation was determined *a priori* as a function of the significance criterion ( ), the statistical power and effect size (ES). Effect size was calculated using the following formula:

$$ES = (\ _1 - \ _0)/S_0$$

Where $_1$ is the mean of the experimental value, $_0$ is the mean of the control value and S_0 is the larger standard deviation of the two means (hence yielding the most conservative effect size) (Kraemer, 1987). For this experiment an effect size of 0.9 was used, based on a relevant literature review of an acute effect of resistance exercise on EPOC (Osterberg et al. 2000). Osterberg et al. measured post 24 hour RMR after 5 sets of circuit training, comprising 10-15 repetitions of 10 exercises at 12RM in 7 young female subjects. Using the equation $ES = (\ _1 - \ _0)/S_0$, the study by Osterberg et al. (2000) had an effect size of 0.92 = [(1479-1419)/65]. Statistical analysis was set at an = 0.05, ES = 0.9 and a statistical power of 0.90, yielding a minimum of 9 subjects (Kraemer, 1987). This number was raised to 10 subjects to increase statistical power.

Values were presented as means ± standard deviations. Baseline values of BMR, baseline VO_2 and post exercise BMR and VO_2 data were analyzed by one-way ANOVA (4 levels of treatments; control, resistance exercise, continuous aerobic exercise and intermittent aerobic exercise) with repeated measures. If there were significant differences in BMR data a Tukey post hoc test was used to determine post hoc pair wise comparisons whether which BMR values from the exercise bouts were different. The level of significance for all tests was set at $P<0.05$.

CHAPTER 4
RESULTS

Ten moderately active college age males volunteered to participate in the study. Subject characteristics along with their maximal measurements of VO_2 and strength are presented in Table 4.1. All subjects achieved physiological VO_2max by meeting at least three out of following four criteria 1) plateau of the oxygen consumption (< 2.0 ml/kg/min) with an increase in exercise intensity 2) attainment of a respiratory exchange ratio of 1.10 or greater 3) attainment of heart rate within ± 10 beat/min or age predicted maximal heart rate 4) and exhaustion or an RPE of 18 or higher (Howley et al., 1995).

Table 4.1 Subject Characteristics (N =10)

Variables	Mean SD	Range
Age (year)	22 2	22-28
Height (cm)	173.8 11.6	155.0-188.0
Weight (kg)	77.1 16.4	61.4-118.2
BMI (kg/m^2)	25.2 4.4	20.3-34.5
VO_2max (ml/kg/min)	34.5 6.1	22.0-42.2
1-RM for Butterflys (kg)	75.0 22.1	63.6-136.4
1-RM for Lat Pulldown (kg)	62.3 26.9	45.5-136.4
1-RM for Triceps Pulldown (kg)	42.7 10.7	27.3-63.6
1-RM for Squat (kg)	80.9 21.2	63.6-136.4

BMI: Body Mass Index; VO_2max: Maximal Oxygen Uptake; 1-RM: One Repetition Maximal; Lat: Latissimus Dorsi

Exercise parameters for the three different protocols are presented in Table 4.2. There were no differences among the three groups in energy expenditure, rate of VO_2 consumed, or exercise duration. The RER obtained during the resistance exercise bout was significantly higher ($F_{2,18}$=7.9, p<0.05, ES=0.47) than the continuous aerobic bout but not the intermittent bout. Average exercise heart rates were significantly higher ($F_{2,18}$=30.3, p<0.05, ES=0.77) for the resistance exercise bout compared to the average heart rates from the continuous and intermittent bouts. The average exercise heart rate from the intermittent bout was significantly higher than the continuous aerobic bout.

Table 4.2 Exercise Parameters for the Three Exercise Protocols[a] (N=10)

Variable	Resistance	Continuous	Intermittent
Energy Expenditure (kcal)	216 19	216 20	218 20
Rate of VO_2 (ml/kg/min)	12.5 1.8	13.3 1.6	13.3 1.8
Exercise Duration (min)	45.0 0.0	43.2 2.3	43.5 1.8
RER	1.07 0.10*	0.92 0.03	0.97 0.13
HR (beat/minute)	126 11‡	99 11	112 8†

Values are means SD;

[a] Metabolic measurements and heart rates were collected continuously and minute averages were averaged over the entire protocol for mean values.

* p<0.05, significantly different from continuous aerobic

‡ p<0.05, significantly different from continuous aerobic and intermittent aerobic

† p<0.05, significantly different from continuous aerobic

Twelve-hour post exercise parameters are presented in Table 4.3. Twelve hours after completing the exercise bouts the resistance bout caused greater increases in metabolic rate compared to the control, continuous, and intermittent exercise bouts ($F_{3,27}$=73.1, P<0.05, ES=0.89). The resistance training bout had a 14.6%, 9.3%, and 4.4% higher metabolic rate 12

hours after exercise compared to the control session and the continuous and intermittent bouts, respectively. The intermittent exercise bout also had significantly greater increases in metabolic rate compared to the control and continuous bouts. The increase in metabolic rate was 9.8% and 4.7%, respectively. There were no differences in body temperature among the four trials.

Table 4.3 Twelve-Hour Post Exercise Metabolic Rate for the Four Protocols[a] (N=10)

	Control	Resistance	Continuous	Intermittent
Metabolic Rate (ml/kg/min)	4.1 0.6	4.7 0.7*	4.3 0.6	4.5 0.6†
RER	0.82 0.03	0.84 0.03	0.81 0.04	0.82 0.04
Body Temperature (C)	37.3 0.2	37.2 0.4	37.3 0.4	37.2 0.5

Values are means SD

RER: respiratory exchange ratio

[a] Metabolic measurements were collected continuously and minute averages were averaged over the 30 minutes for mean values.

*p<0.05, significantly different from control, continuous, and intermittent exercise

†p<0.05, significantly different from control and continuous aerobic exercise

Post exercise BMR is presented in Table 4.4. Basal metabolic rate was significantly higher ($F_{3,27}$=22.5, P<0.05, ES=0.71) after the resistance exercise bout compared to the control, continuous, and intermittent bouts. Basal metabolic rate for the resistance bout was 15.6% higher from the control session and 15.6% and 12.1% higher than the continuous and intermittent bouts, respectively. Kilocalories were calculated for the 24-hour period after the exercise bouts. Kilocalorie expenditure following the resistance training bout was significantly higher ($F_{3,27}$=18.23, P<0.05, ES=0.67) than the control, continuous, and intermittent bouts. Kilocalorie expenditure for the resistance bout was approximately 10.1% higher from the control session and 10.7% and 8.0% higher than the continuous and intermittent bouts, respectively. Respiratory exchange ratio was significantly higher ($F_{3,27}$=6.95 P<0.05, ES=0.44) at the control session compared to the resistance, continuous and intermittent sessions. There were no significant differences in body temperature and body composition after the four sessions.

Table 4.4 Post Exercise Basal Metabolic Rate for the Four Protocols[a] (N=10)

	Control	Resistance	Continuous	Intermittent
BMR (ml/kg/min)	3.2 0.4	3.7 0.5*	3.2 0.4	3.3 0.5
BMR (kcal/day)	1710 207	1883 193*	1701 197	1743 198
RER	0.88 0.02‡	0.83 0.03	0.82 0.04	0.84 0.04
Body Temperature (C)	36.8 0.2	36.7 0.3	36.9 0.2	36.9 0.3
Body Fat (%)	11.0 3.3	11.4 3.5	11.1 3.3	11.3 4.1

Values are means SD

BMR: basal metabolic rate; RER: respiratory exchange ratio

[a] Metabolic measurements were collected continuously and minute averages were averaged over the 30 minutes for mean values.

*$p<0.05$, significantly different from control, continuous, and intermittent exercise

‡$p<0.05$, significantly different from resistance, continuous and intermittent sessions

CHAPTER V

DISCUSSION

The present study is the first study that has been completed comparing the effects of resistance exercise, continuous aerobic exercise, and intermittent aerobic exercise, while keeping rate of oxygen uptake (VO_2), exercise duration, and calorie expenditure constant during three exercise protocols, on basal metabolic rate (BMR). The main finding from this investigation is that resistance exercise significantly elevated metabolic rate and BMR for up to 21 hours compared to the control session, and the continuous aerobic and intermittent aerobic protocols. Therefore, the research hypothesis was accepted that a bout of resistance exercise would have a greater effect on BMR compared to bouts of continuous and intermittent aerobic exercise that was matched for calorie expenditure (kcal) and rate of oxygen consumption.

Whether resistance exercise is a better modality than aerobic exercise in helping to control weight is a matter of debate. Many researchers have tried to seek an answer by comparing the acute effects of aerobic exercise and resistance exercise on BMR (Burlesson et al., 1998) and/or the effect of aerobic training and resistance training on BMR (Broeder et al., 1992; Brett et al., 1998; Geliebter et al., 1997). However, comparing aerobic exercise with resistance exercise is problematic due to difficulty in making fair comparisons between resistance and aerobic exercise. The major flaw in the experimental designs of most studies is that they do not match exercise parameters between aerobic training protocols and resistance training protocols in the amount of kcal spent, oxygen consumption, exercise intensity, and/or exercise duration (Dolezal et al., 1998; Broeder et al., 1992; Geliebter et al., 1997). Therefore, it is not surprising that results are mixed, since there are differences in methodology among the different research studies. For example, Broeder et al. (1992) found no statistical difference in RMR between pre and post measurements after 12 weeks of resistance training or endurance training (control: 5.53 0.17 vs. 5.48 0.13; resistance: 5.36 0.17 vs. 5.53 0.21; endurance: 5.23 0.13 vs. 5.32 0.13 kJ/min; pre vs. post training). However, Dolezal et al. (1998) reported after 10 weeks of

training that BMR measurements in the resistance training group were significantly increased from pre to post measurements compared to an endurance training group (resistance training: 7613.3 968.7 vs. 8090.8 951.2*; endurance training: 7231.2 554.1 vs. 7029 666.4 kJ/day; pre vs. post training;* P< 0.05). In both studies the resistance training and the aerobic training groups were only matched for the number of exercise days per week (subjects in each group exercised 4 days per week in Broeder's study and 3 days per week in Dolezal's study). The reason why the study by Dolezal et al. (1998) found differences between resistance training and endurance training and Broeder et al. (1992) did not is difficult to say but Dolezal et al (1998) may have had subjects exercising at higher intensities. Dolezal et al (1998) also had subjects exercising three times a week as opposed to four times a week in the study by Broeder et al (1992). Perhaps different training adaptations occurred between the two different studies, which caused a differing effect on 48 hour RMR. Since training adaptations can have different influences on metabolic rate the purpose of the present study was to evaluate the acute effects of resistance and aerobic exercise on moderately trained subjects.

To the best of my knowledge, a study by Burlesson et al. in 1998 was the only study comparing an acute effect of resistance exercise and aerobic exercise on RMR that held exercise intensity constant between resistance and aerobic exercise. Burlesson et al. (1998) reported that resistance exercise had significantly higher total oxygen consumption during 30 minutes of recovery than steady state aerobic exercise (19.0 vs. 12.7* L, respectively; *P<0.05). These results are somewhat similar to what was found in the present study. However, these authors commented that the energy expenditure from either the resistance or aerobic exercise in their study was not likely to make a substantial impact on body weight even if performing these exercises several times per week. Since the resistance and aerobic exercise protocols used in their study were of relatively low intensity and duration the authors commented that perhaps higher volumes of resistance exercise may have produced higher EPOC and therefore may have been sufficient to affect body weight and body composition. Most recommendations for preventing the transition to overweight or obesity is moderate exercise lasting at least 45 to 60 minutes (Macknigh et al., 2003). One point that needs to be mentioned here is that it has been shown that high intensity intermittent aerobic exercise produces higher EPOC than continuous aerobic exercise with the same energy expenditure (Zoladz et al., 1998; Borsheim et al., 1998; Dawson et. al, 1996), it would therefore be more interesting to compare resistance exercise and

intermittent aerobic exercise. Therefore, our study was designed to focus on comparing the acute effects of a resistance exercise with a high intensity intermittent aerobic exercise, matching both rate of VO_2 and amount of energy expenditure lasting for a duration of 45 minutes.

In the present study we found that the resistance exercise bout had a 14.6%, 9.3%, and 4.4% higher metabolic rate 12 hours after exercise compared to the control session and the continuous and intermittent bouts, respectively. The intermittent exercise bout also had significantly greater increases in metabolic rate compared to the control and continuous bouts. The increase in metabolic rate was 9.8% and 4.7%, respectively. The RER and heart rate during the resistance exercise session were also significantly higher than both continuous and intermittent aerobic exercise sessions (RER: 1.07 0.10*, 0.92 0.03, 0.99 0.11; heart rate: 126 11*, 99 11, 112 8 b/min; resistance exercise, continuous aerobic and intermittent aerobic exercise, respectively; *P<0.05). The higher RER indicated that a higher percentage of carbohydrate was utilized during resistance exercise compared to the two aerobic exercise protocols. Burlesson et al., (1998) also reported similar findings when comparing RER (0.92 0.01* vs. 0.77 0.01; *P<0.05) and heart rate (140 4* vs. 110 3 beat/min; *P<0.05) between resistance exercise and steady state aerobic exercise, respectively. So even though the resistance exercise was matched for kilocalories, exercise duration, and rate of VO_2 it still created a greater physiological response than the continuous and intermittent aerobic exercises.

Comparing the difference between the intermittent aerobic exercise and continuous aerobic exercise at 12 hour post exercise, our findings (post 12-hour metabolic rate; 0.34 0.03* vs. 0.32 0.02 L/min; *P<0.05) are consistent with the results from other researchers that have found intermittent aerobic exercise to produce higher EPOC values compared to continuous aerobic exercise, matched for calorie expenditure (Larforgia et al., 1997; Frey et al., 1993). Larforgia et al., (1997) reported that intermittent exercise produced significantly higher EPOC values after 9 hours post exercise than continuous aerobic exercise when calorie expenditure was held constant between exercise bouts (9-h EPOC; 15.0 3.3* vs. 6.9 3.8 L; *P<0.05).

However, our results are in contrast with some researches, which were able to demonstrate significantly higher EPOC measurements after continuous aerobic exercise for up to 24 hours. The reason for the differences between our study and that of Wither et al. (1991) and Bielinski et al. (1985) may be due to the different exercise intensities and durations. In our study

during the continuous aerobic exercise session, subjects cycled at approximately 40% of their VO_2max for 45 minutes. In the study by Wither et al. (1991), subjects ran on a treadmill at 70% of VO_2 max for 164 minutes. The authors reported a 23.7% increase in 8-hour RMR (32.4 L; 154.5kcal) and Bielinski et al. (1985) reported a 4.7% increase in the 24-hour post exercise RMR after running on a treadmill for 3 hours at 50% of VO_2max (1.44 0.06* vs. 1.37 0.05 kcal/minute; *P<0.05). Both studies used an ultra long duration exercise protocol, which is impossible for most sedentary or overweight individuals to perform. When designing studies for weight loss, it is important to design an exercise protocol to fit with the capabilities of a sedentary population, since these are the individuals that will benefit most from the increases in RMR.

Twenty-one hour BMR, in the present study, for the resistance bout was 15.6% higher from the control session and 15.6% and 12.1% higher than the continuous and intermittent bouts, respectively. Kilocalorie expenditure for the resistance bout was approximately 10.1% higher from the control session and 10.7% and 8.0% higher than the continuous and intermittent bouts, respectively, which would be equal to an increase in total daily energy expenditure of at least 180 kcal/day. This number represents approximately half of the normal energy used by an untrained individual to exercise for 45 minutes at a moderate intensity. Energy expenditure after the resistance exercise bout alone should not be neglected since it could translate to a weight loss of one and a half pounds per month.

Our results are comparable to two studies that evaluated the effects of heavy resistance training on RMR in young and older adults. Dolezal et al. (2000) and Schuenke et al. (2002) both reported an increase in RMR for up to 48 hours following resistance exercise. Dolezal et al. (2000) reported an 18% increase in the 24-hour RMR, and an 11% increase in the 48-hour RMR. Schuenke et al. (2002) found a 20% increase in the 48-hour RMR. Our study found approximately a 10% increase in 24-hour BMR. The main reason why our study had smaller increases in BMR was due to the intensity level in the resistance exercise protocol. In Dolezal's study the resistance exercise protocol in contrast to the present study was designed to induce muscle damage whereas the present study's resistance exercise protocol was designed to avoid muscle damage. The exercise protocol in the study by Schuenke et al. was also very demanding and only suited for people who were experienced with weight training. Our exercise protocol was designed to minimize muscle damage and was designed for sedentary to moderately trained

individuals who had little or no experience in weight training. Even with the lighter weights and minimal muscle damage BMR was still increased 21 hours following the resistance training protocol.

Factors affecting post exercise recovery rates include replenishing the phosphagen system; restoring hemoglobin and myoglobin; meeting the elevated energy demands from the cardiac and respiratory muscles (Harris et al., 1976; Boutellier et al., 1984; Gaesser et al., 1984); restoring increases in muscle blood flow (Adersen et al., 1985); restoring the redistribution of body fluids (Rostein et al., 1998); removing lactate (Brooks et al., 1999; McArdle et al., 2000); meeting the demands of increases in protein synthesis (Welle et al., 1990); resynthesizing glycogen storage (Ivy et al., 1998; Pascoe et al., 1996); meeting the demands of circulating hormones (Borsheim et al., 1998); meeting the demands of increases in body temperature (Gaesser et al., 1984); and meeting the demands of increased lipid oxidation (Trost et al., 1997, Borsheim et al., 1998). Anaerobic exercise, particularly resistance training, can cause greater disturbances in physiological processes as seen by the higher heart rate and RER during the resistance exercise bout compared to the continuous and intermittent exercises.

Many of the mechanisms mentioned above such as replenishing the phosphagen system; restoring hemoglobin and myoglobin; meeting the elevated energy demands from the cardiac and respiratory muscles, restoring increases in muscle blood flow and body fluids, and removing lactate to pre-exercise levels occur rather quickly at the end of an exercise bout and would not cause an increase in metabolic rate 12 to 21 hours after the completion of exercise. Other mechanisms such as the increases in protein synthesis, resynthesis of glycogen storage, increases in circulating hormones, increases in body temperature, and increases in lipid oxidation may take longer than 12 hours to return to baseline following a bout of exercise.

Although mechanisms were not evaluated in the present study body temperature was measured in the subjects during their metabolic measurements. The alteration of body temperature plays an important role in the body's metabolic rate, and the increases in tissue temperature and EPOC are very closely associated. A one degree Celsius increase in body temperature elevates BMR by approximately 10%. The enzymatic reaction would be doubled for every 10 degree Celsius increase in body temperature due to the Q10 effect. The main mechanism being that an increase in body temperature decreases metabolic efficiency; phosphorylation coupling and energy tapping (Gaesser et al., 1984). Hence, higher oxygen

consumption would be necessary for a given amount of ATP to be synthesized. The elevated temperature might also cause substrate cycling, which is also referred to as futile cycling (Newsholme 1978; Bahr et al., 1990). However, in the present study there were no differences recorded in body temperature across the three protocols and control session at 12 hours and 21 hours post exercise. Some studies have reported positive relationship between BMR and body temperature (Gaesser et al. 1984; Newsholme 1978; Bahr et al., 1990; Larforgia et al., 1997). The difference between the present study and previous studies may be due to the use of an oral thermometer rather than a rectal thermometer, which may be less accurate compared to measuring core temperature.

Other factors such as the residual effects of hormones and resynthesis of glycogen may also contribute to the elevated metabolic rate. Researches have reported increased plasma growth hormone and norepinephrine level after exercise (Borsheim et al., 1998; Boisseau et al., 2000) and their effects on metabolism may last for several hours. Growth hormone promotes lipolysis, and there is evidence that plasma growth hormone levels increase significantly from resting levels after 40 minutes of exercise. The extent of elevation is directly related to exercise intensity and duration, with less fit individuals having a greater response than those who are fitter (Warren et al., 2000). No differences in 24-growth hormone release have been reported between continuous exercise and intermittent exercise. The pattern of growth hormone response to acute resistance exercise has been found to be similar to acute aerobic exercise, with the same average peak growth hormone concentration of 5-25 µg/L attained during both resistance and aerobic exercise (Nindl et al., 2001, Raastad et al., 2000, Takarada et al., 2000, Kraemer et al., 1999a, Kanaley et al., 1997, 2001, Weltman et al., 1997, Pritzlaff et al., 1999). There is some evidence that catecholamine levels are higher after intense anaerobic exercise than after prolonged aerobic exercise (Boisseau et al., 2000) but these effects do not usually last more than a few hours.

The rate of muscle glycogen synthesis is directly linked to the intensity of the exercise. The rate of muscle glycogen synthesis in short-term high intensity exercise (100% of VO_2 max) is greater than that in prolonged low intensity exercise (70% of VO_2max; 15.1-33.6 mmol/kg/h vs. 1.5-2 mmol/kg/h; Pascoe et al., 1996). Interestingly, resistance exercise, which is theoretically similar to high intensity interval exercise in terms of work/rest protocols, has a lower glycogenesis rate than short-term high intensity exercise (1.9 – 11.1 mmol/kg/h). The lower rate of glycogenesis might be due to the component of eccentric contraction of resistance

exercise, as this leads to more muscle damage, which might deter the process of glycogenesis (Pascoe et al., 1996).

In our study, RER was significantly higher during the resistance exercise session compared to both the aerobic exercise sessions (RER: 1.07 0.10*, 0.92 0.03, 0.97 0.11; resistance exercise, continuous aerobic, intermittent aerobic; *P< 0.05). This means a greater amount of glycogen was used during the resistance exercise session. Glycogen resysthesis has a biphasic pattern, similar to the pattern of EPOC and the slow phase can last up to five hours (Ivy et al., 1998). So glycogen resynthesis may have had a small impact on the 12-hour metabolic rate however there were no differences in RER among the three groups at the 12 and 21-hour metabolic measurements.

The main mechanism influencing the higher metabolic rate at 12 and 21 hours after resistance exercise is most likely due to an increase in protein turnover. Since the resynthesis of protein is energetically expensive, and already accounts for 15-20% of BMR during resting conditions. Resistance exercise usually produces a certain degree of muscle damage, which will increase protein systhesize. Dolezal et al. (2000) reported a correlation between muscle damage and an increase in BMR and hypothesized that the increase in BMR was due to the increase in protein synthesis due to muscle damage. Dolezal et al., (2000) reported that creatine kinase significantly increased from baseline up to 72 hours post exercise (320.4 20.1*, 1140.3 37.1*, 675 41.7* U/L; 24h post exercise, 48h post exercise and 72h post exercise respectively, *P<0.05, significantly different from baseline) after an acute resistance exercise with an eccentric work load. However, this increase in BMR from protein resynthesis rates may only be seen in the early stages of a resistance training program and may be attenuated as one becomes adapted to the protocol. In the present study subjects that were moderately active were recruited so muscle damage could be minimized. Subjects were also exercised with a protocol that utilized multiple muscle groups at a lower intensity (50-60% of 1-RM). Although muscle damage markers were not measured and subjects did not complain of being sore during their metabolic measurements, the acute resistance exercise bout in the present study must have produced a certain degree of ultrastructural damage (microscopic tears in contractile proteins muscle cells) that stimulated increased muscle protein synthesis and thereby increased BMR (Evan, 2004).

Limitations

As previously described, participants in this study were volunteers, healthy moderately active college-aged males so they were not a true representation of a physically inactive or overweight population. Therefore, inferring to a broader population from this sample must be done with care. One of the problems with the testing procedures is that the subjects did not live in the laboratory over the entire testing protocol. Therefore, dietary records and daily physical activity outside the laboratory relied on the accuracy of self-reports. The study did not measure muscle enzymes or record subjects' pain perceptions so there was no true measurement or indicator of muscle damage or the amount of muscle damage. Muscle damage has been shown to substantially increase metabolic rates (Dolezal et al., 2000). However, intentionally induced muscle damage to increase BMR was not the goal of this study. The goal of the study was to try and replicate exercise bouts that a sedentary to moderately active group of individuals would do if they were participating in an exercise program to help them lose weight. Since most sedentary or overweight individuals are not athletes looking for benefits in performance most will not exercise or continue to exercise if they experience a great deal of pain and discomfort during or after an exercise bout. Therefore, we tried to minimize muscle damage by using relatively light weights over multiple exericses. Anecdotally none of our subjects complained of being sore from the resistance exercise.

Another consideration when examining the results of the present study is that the main objective of this study was to compare two modalities with a resistance training protocol of similar intensity and energy expenditure. The continuous aerobic and intermittent aerobic exercise sessions were based on rate of VO_2 and amount of energy expenditure during the resistance protocol. Therefore, energy expenditure and exercise intensity levels are lower than what indivduals would normally perform during a usual exercise bout. Most of the subjects said that the continuous exercise bout was quite easy and they could have exercised for a greater duration or intensity. Therefore, the aerobic and intermittent sessions in the present study did not create large disturbances in metabolic rates after exercise.

Another limitation to the study was that the exercise bouts were not randomized. The sequence of the control, resistance, continuous aerobic, and intermittent aerobic was similar for all subjects. In the present study, subjects did not have a familirarity period before the control session. Changing sleeping environment and disrupting sleep cycles may have caused the RER

to be higher during the control session's BMR measurement compared to the resistance, continuous and intermittent sessions (RER: 0.88 0.02*, 0.83 0.03, 0.82 0.04, 0.84 0.04; *P<0.05). However, we do not believe that not randomizing the order of testing influenced any of the metabolic measurements.

Recommendations for Future Research

Our study measured the acute effect of exercise approximately 12 and 21 hours after a bout of exercise. We believe that an elevated BMR for at least one day after an exercise bout is needed to make a tangible impact on TDEE. The participants in the current study were moderately active college age Caucasian and African American men. Since this study was a stepping stone to compare metabolic rates among three exercise protocols matched for energy expenditure, oxygen consumption, and duration future investigations should be conducted on different populations such as overweight and obese individuals, women, elderly and other ethnic groups. African-American and Mexican American women have some of the highest overweight and obesity rates with 50% of African-American and Mexican-American women meeting the definition of obesity (BMI>30), while 34.7% of women in the United State of America meet the criteria for obesity (Flegal et al., 1994). However, care needs to be taken in studying premenapausal women due to their hormonal fluctuations since hormones can have an impact on metabolic rate. Well-controlled studies by Solomon et al. (1982) and Bisdee et al. (1989) have demonstrated cyclical changes in women's BMR. Both studies found BMR to be the lowest approximately one week before ovulation and the highest before the menstrual period (6024 351 vs. 6643 817 kJ/d; late follicular vs. late luteal; P<0.001). These changes were mainly due to the cyclical nature of progesterone.

Another interesting area of research would be to examine whether the acute effects of exercise on BMR still exists after chronic training. Cross sectional studies have reported that trained individuals have lower BMR changes after similar bouts of exercise compared to untrained individuals possibly due to chronic adaptations from training (Dolezal et al., 2000). However, there are no longitudinal studies comparing the acute effects of resistance exercise training without the primary purpose of causing muscle damage, to determine whether resistance exercise will have long-term weight control benefits. Therefore, it would be interesting to

conduct longitudinal studies studying the effect of training on the acute effects of both resistance and intermittent aerobic exercise.

Conclusions

The results from the present study showed that resistance exercise significantly increased 9 hour and BMR compared to continuous aerobic exercise and intermittent aerobic exercise equalized for the rate of VO_2 uptake, exercise duration, and calorie expenditure. Metabolic rate and BMR after resistance exercise was found to increase by approximately 14.5% and 10% at 9 and 21 hours post exercise, which would be equal to an increase in total daily energy expenditure of roughly180 kcal/day. This number represents about half of the normal energy used by an untrained individual to exercise for 45 minutes at a moderate intensity. Energy expenditure from EPOC alone could translate to a weight loss of one and a half pounds per month and should not be neglected. This could have important implications for helping to reduce or maintain body weight in overweight or obese individuals. The present study supports the idea of using resistance exercise as an alternative or at least in conjunction with aerobic exercise protocols for reducing weight. This finding may be important since many obese individuals have orthopedic limitations which can make traditional aerobic exercise regimens such as walking difficult to do at a high enough intensity or duration in order to reduce body weight.

APPENDIX A

Flyer

Do you want to know the best way to reduce your weight?

Do you still have an old notion that jogging is the best way to reduce your body weight? Scientific evidence shows that weight training may be better for controlling weight.
By participating in this research project you will find out what type of exercise is the best for reducing your weight.

Must be:

Healthy male 18 to 35 years of age
Not taking weight control pills or supplements

What will you have to do?

Come to exercise physiology laboratory at Sandels one day a week for 4 weeks to exercise and be tested.

NO BLOOD WILL BE DRAWN

Benefit of participation

Know your maximal aerobic capacity and Muscle strength
Good Karma for helping Ph.D. student finish his dissertation
Know what type of exercise is the best for you if you want to control your weight

Please contact: Prawee 850-339-5678 or ps02c@fsu.edu

ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or	ps02c@fsu.edu or

APPENDIX B

Informed Consent

Florida State University

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8633 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 11/3/2005

To:
Prawee Sirithienthad
Mc 1493

Dept.: **NUTRITION FOOD AND MOVEMENT SCIENCES**

From: **Thomas L. Jacobson, Chair**

Re: **Use of Human Subjects in Research**
A comparison of the effects of post exercise basal metabolic rate among continuous aerobic, intermittent aerobic, and resistance exercise: implications for weight control

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Human Subjects Committee at its meeting on **10/19/2005**. Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals which may be required.

If the project has not been completed by **10/18/2006** you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. The principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

cc: Lynn Panton
HSC No. 2005.799

A comparison of the effects of post exercise basal metabolic rate among continuous aerobic, intermittent aerobic, and resistance exercise: Implications for weight control

Informed Consent Form

I, _____, freely and voluntarily and without element of force or coercion, consent to be a partipant in the research project entitled "A comparison of the effects of post exercise basal metabolic rate among continuous aerobic, intermittent aerobic, and resistance exercise: Implications for weight control."

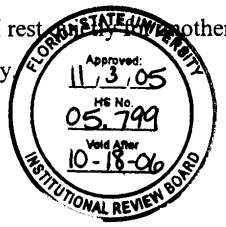
This research is being conducted by Prawee Sirithienthad, who is a graduate student under the supervision of Dr.Lynn Panton Assistant Professor in the Department of Nutrition, Food and Exercise Sciences at The Florida State University. I understand that the purpose of their research project is to better understand the metabolic rate differences after three types of exercise bouts. The research will be conducted during a four week period. I will be asked to come into the laboratory for one control session and three separate exercise bouts; a resistance exercise bout, a continuous aerobic exercise bout and an intermittent aerobic exercise bout. All told, I will be asked to make three visits to the laboratory at 9.00 am to undergo exercise testing (approximately 45 minutes each) and four visits at 9.00 pm for measuring 12-hour post exercise metabolic rate and basal metabolic rate (staying in the laboratory from 9.00 pm to approximately 7.30 am the following morning, see Figure 1. for research protocol).

I understand that the procedures will be as follows:

Today I will be asked to fill out a questionaire about my medical history, tobacco history and family history and sign an inform consent. I will then be scheduled for a control session and will be asked to record my dietary intake for the three days prior to my control session visit. This three day dietary record will be replicated before each of my three exercise bouts.

During the control session I will be asked not to eat anything after 6.00 pm and drink only water. I will be asked to come to the laboratory at approximately 9.00 pm to have my baseline VO2, measured and I will stay over night at the laboratory and have my measured basal metabolic rate, body compostion, maximal oxygen consumption and maximal strength measured the following morning.

When I arrive at the laboratory at 9:00 pm I will rest in the supine position for 30 minutes then I will be asked to wear a ventilation mask that will collect my expired air so that my resting metabolic rate can be measured. I will wear the mask while I rest [illegible] another 30 minutes. After this measurement I will spend the night in the laboratory.



_____
(Subjects Initials)

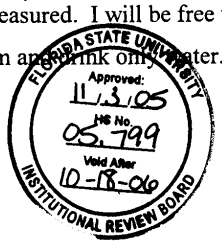
A comparison of the effects of post exercise basal metabolic rate among continuous aerobic, intermittent aerobic, and resistance exercise: Implications for weight control

I will be awakened at 6:00 am to have my basal metabolic rate (BMR) measured. I will be instructed to minimize physical activity, by dressing slowly and not taking a shower. I will walk to the testing area and will rest in the supine position for 30 minutes then I will ask to wear a ventilation mask and rest quietly for another 30 minutes.

After the completion of my BMR I will be asked to undergo a bone scan by a trained radiological technician. This test requires that I lie still on a padded bench for a period of less than 30 minutes while a full body scan is performed to determine bone mineral density and estimate my body composition. The risks during this type of test are minimal to a healthy individual and have been approved for use on human subjects. I will be exposed to a low intensity X-ray. I will also have my body composition measured by assessing my skinfolds. A skinfold caliper will be ussed to gently pinc my skin on the back of my arem, my chest and my abdomen.

Following my body composition measurement, I will be asked to perform a cycle test to determine my maximal oxygen consumption. The resistance of the cycle will be gradually increased every few minutes until I can not pedal any longer. I will be asked to wear a mouthpiece with a nose clip to collect my expired air to determine my oxygen consumption. I will be free to stop the test at any time. I will then be asked to perform a maximal weight lifting test on the following exercises: vertical butterfly, squat, toe raises, lateral pulldown, and triceps press down.

I will return to the laboratory one week later after replicating my dietary record that I completed the previous week for the control session. During the resistance training session I will be asked to perform circuit weight training composing of vertical butterflys, squats, toe raises, lat pulldowns and triceps press down. All exericises will be performed at approximately 50-60% of my maximal strength tests that were recorded a week ago. For each exercise, I will be asked to perform as many repetitions as I possible can followed by 60 seconds of rest. I will continue going through the exercises until I have completed 45 minutes of training. Exercise duration for the resistance exercise session will be fixed at 45 minutes. During the 45 minute bout of resistance exercise, I will be asked to wear a mouthpiece with a nose clip so that my oxygen consumption and calorie expenditure can be measured. I will be free to stop the test at any time. I will be asked not to eat anything after 6.00 pm and drink only water. I will be asked to return to



(Subjects Initials)

the laboratory at 9.00 pm to have my 12-hour post exercise VO2 measured and stay overnight in the laboratory and will have my BMR measured in the morning.

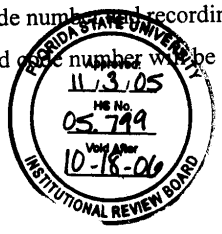
I will return to the laboratory one week later after replicating my dietary record that I completed the previous week before the resistance exercise session. I will report to the laboratory at 9.00am and cycle on the cycle ergometer at moderate intensity. Exercise duration for the continuous aerobic exercise session will be approximately 40-50 minutes. During the exercise bout, I will be asked to wear a mouthpiece with a nose clip so that my oxygen consumption and calorie expenditure can be measured. I will be free to stop the test at any time. I will again be asked not to eat anything after 6.00 pm and drink only water. I will return to the laboratory at 9.00 pm to have my 12-hour post exercise VO2 measured and stay overnight in the laboratory and will have my BMR measured in the morning.

I will return to the laboratory one week later after replicating my dietary record that I completed the previous week before the continuous aerobic exercise session. I will report to the laboratory at 9.00 am and will cycle on the cycle ergometer alternately between high intensity and low intensity. Exercise duration for this session will be approximately 40-50 minutes. During the exercise bout, I will be asked to wear a mouthpiece with a nose clip so that my oxygen consumption and calorie expenditure can be measured.. I will be free to stop the test at any time. I will be asked not to eat anything after 6.00 pm and drink only water. I will return to the laboratory at 9.00 pm to have my 12-hour post exercise VO2 measured and stay overnight in the laboratory and will have my BMR measured in the morning.

I will be asked to avoid any vigorous physical activity at least 2 days before each exercise session and refrain from smoking at least 12 hours before each session.

The possible benefits of my participation in this research project include learning about my fitness levels, my body composition and how exercise affects my metabolism. I will also be given a number of tests free of charge and the results will be given to me.

The results of this research study may be published but my name or identity will not be revealed. Information obtained during the course of the study will remain confidential, to the extent allowed by law. My name will not appear on any of the results. No individual responses will be reported. Only group finding will be reported in publications. Confidentially will be maintained by assignning each subject a code number and recording all data by code number. The only record with the subject's name and code number will be kept by the principal



(Subjects Initials)

investigator, Prawee Sirithienthad, in a locked drawer in his office. Data will be kept for 10 years and then destroyed.

In case of an injury first aid will be provided to me by the laboratory personnel working on the research project any other treatment or care will be provided at my expense.

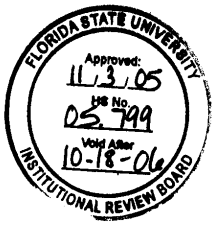
Any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by the investigators or they will refer me to a knowledgeable source. I understand that I may contact Prawee Sirithienthad (850) 339- 5678 or Dr.Lynn Panton (850) 644-4685 for answers to questions about this research project or my rights. Group results will be sent to me upon my request.

In case of injury, or if I have questions about my rights as a suject/participatnt in this research, or if I feel I have been placed at risk, I can contact the chair of the Human Subjects committee, Institutional Review Board, through the Office of the Vice President for Research, at (850) 644-8633.

The nature, demand, benefits and risks of the project have been explained to me. I knowingly assume any risks involved.

I have read the above informed consent form. I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefits to which I may otherwise be entitled. In signing this consent form, I am not waiving my legal claims, rights or remedies. A copy of this consent form will be given to me.

(Subject) (Date)



(Subjects Initials)

APPENDIX C

Institional Review Board

FLORIDA STATE UNIVERSITY *Application No.:*

Human Subjects Application
to the INSTITUTIONAL REVIEW BOARD
for RESEARCH INVOLVING HUMAN SUBJECTS

The Federal Government and University policy require that the use of human subjects in research be monitored by the Institutional Review Board (IRB). **The following information must be provided** when humans are used in research studies, whether internally funded, extramurally funded or unfunded. Research in which humans are used may not be performed in the absence of IRB approval.

PLEASE COMPLETE AND SUBMIT PAGES 1 AND 2 plus YOUR ANSWERS TO THE QUESTIONS (on page 3) IN TYPEWRITTEN FORM TO: HUMAN SUBJECTS COMMITTEE, Mail Code 2763, or

2035 E. Paul Dirac Drive, Box 15

100 Sliger Bldg., Innovation Park
Tallahassee, FL 32310

Researcher: Prawee Sirithienthad **Date:** 09-25-05

Project Title: A comparison of the effects of post exercise basal metabolic rate among continuous aerobic, intermittent aerobic, and resistance exercise: Implications for weight control.

Project Period (starting/ending dates): from Oct 2005 to Oct 2006

Position in University (faculty, etc.) If student, please indicate FSU Faculty Advisor:

Graduate student under the supervision of Dr.Lynn Panton

Department: Nutrition, Food and Exercise Sciences

Telephone: 339-5678 E-Mail Address: ps02c@fsu.edu
(where you can be reached in case of a problem with your application)

Mailing Address (where your approval will be mailed):

436 Sandels Building

Project is (please check one): **__x__ dissertation** **___ __ teaching** **_____ thesis** **_____ other**

Project is: ____x ___unfunded **_____ funded** *(if funded, please complete the following):*

Funding Agency (actual/potential):

Contract/Grant No. (if applicable): _____

FOR EVALUATION OF YOUR PROJECT, PLEASE CHECK THE FOLLOWING WHICH APPLY:

	Mentally or Physically Challenged Subjects	x	**Subjects studied at FSU**
	Children or Minor Subjects (under 18 years old)		Subjects studied at non-FSU location(s)
	Prisoners, Parolees or Incarcerated Subjects	X	**Students as Subjects**
	Filming, Video or Audio Recording of Subjects		**Employees as Subjects**
x	**Questionnaires or Survey(s) to be administered**		**Pregnant Subjects**
	Review of Data Banks, Archives or Medical Records		Fetal, placental or surgical pathology tissue(s)
	Subjects' major language is not English		Involves Blood Samples (fingerpricks/venipuncture
	Involves Deception (if yes, fully describe at Question No. 7)		**Subjects to be paid**
	Exclusion of Women or Children Subjects (must explain why they are being excluded)		**Oral History Project**

Survey Techniques: Check applicable category if the only involvement of human subjects will be in one or more of the following categories:

_____ Research on normal educational practices in commonly accepted educational settings

_____ Research involving educational tests (cognitive, diagnostic, aptitude, achievement)

_____x_____ Research involving survey or interview procedures *(if checked, please see below)*

_____ Research involving the collection or study of existing data, documents, records, specimens

If research involves use of survey or interview procedures to be performed, indicate:

1. *Responses will be recorded in such a manner that human subjects cannot be identified, by persons other than the researcher, either directly or through identifiers linked to the subjects.*

   _x__yes ___ no

2. *Would subject's responses, if they became known outside the research, reasonably place the subject at risk of criminal or civil liability or be damaging to the subject's financial standing or employability.*

   ___yes _x__no

3. *The research deals with sensitive aspects of the subject's own behavior, such as illegal conduct, drug use, sexual behavior, or use of alcohol.*

___yes

_x__no

Does Research Involve Greater Than Minimal Risk to Human Subjects? _____ Yes ___x_____ No
(If yes, explain in full at Question No. 2)

"Minimal Risk" means that the risks of harm anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.

I HAVE READ THE FLORIDA STATE LETTER OF ASSURANCE FOR THE PROTECTION OF HUMAN SUBJECTS IN RESEARCH AND AGREE TO ABIDE BY IT. I ALSO AGREE TO REPORT ANY SIGNIFICANT AND RELEVANT CHANGES IN PROCEDURES AND INSTRUMENTS AS THEY RELATE TO SUBJECTS TO THE CHAIR, HUMAN SUBJECTS COMMITTEE, OFFICE OF RESEARCH.

RESEARCHER (signature) (Date)

FSU FACULTY ADVISOR (signature) (Date)
(Application will not be processed without Advisor's signature)

Questions
FOR RESEARCH INVOLVING HUMAN SUBJECTS

USE ADDITIONAL SHEETS FOR ANSWERING THE FOLLOWING QUESTIONS
PLEASE SUBMIT YOUR ANSWERS IN TYPEWRITTEN FORM

1. GIVE A COMPLETE DESCRIPTION OF YOUR RESEARCH PROCEDURES AS THEY RELATE TO THE USE OF HUMAN SUBJECTS.

Specific Aim.
To compare of the effects of post exercise basal metabolic rate among continuous aerobic, intermittent aerobic, and resistance exercise: Implications for weight control.

Description of Study.
Subjects (n=10) will consist of moderately active, healthy males, with a body mass index less than 25 kg/m^2 between the ages of 18-35 years and will be recruited from Florida State University and the surrounding community. A control session will consist of measurements of body composition using Dual energy X-ray absorptiometry system(DEXA scan) and Lange skinfold calipers, strength measurements, measurements of aerobic fitness (VO_2max), baseline oxygen consumption (VO_2) and baseline basal metabolic rate (BMR). After the control session subjects will undergo three exercise bouts one of resistance exercise, one of continuous aerobic exercise and one of intermittent aerobic exercise. Each of the three exercise bouts will be separated by one week. Post exercise metabolic rate will be measured approximately 12 and 21 hours after each one of the three exercise bouts using the Truemax 2400 Metabolic Measurement System. Each exercise bout will be designed so the subject will produce the same amount of energy expenditure and rate of VO_2 when exercising.

The resistance exercise bout will be completed first and consist of performing several sets of five exercises: vertical butterflys, squats, toe raises, lateral pull-downs, and triceps press downs on a Smith weight training machine. The resistance exercise bout will last for 45 minutes. During the resistance exercise, subject's expired air will be collected continuously through a mouth piece and a plastic tube that will be connected to the metabolic cart. The gas parameters from the subject's expired air will be used to calculate total energy expenditure and average rate of VO_2.

The continuous aerobic and intermittent aerobic exercise bouts will follow the resistance exercise bout and consist of cycling on a cycle ergometer (Monark 818 E Ergomedic) again subject's expired air will be collected and analyzed. Subjects will cycle on the cycle ergometer at a work load that produces the same total energy expenditure and rate of VO_2 that were measured during the resistance exercise

bout. During the continuous aerobic bout subjects will cycle at approximately 40-50% of their VO_2max. For the intermittent aerobic exercise bout, subjects will cycle alternately between high intensity at approximately 90%-100% of VO_2max and low intensity at approximately 25-30% of VO2max. Twelve hours following each of three exercise bouts, subjects will return to the laboratory to have their 12-hour post exercise VO_2 assessed, and will stay overnight at the laboratory and have their BMR (21-hour post exercise) measured at 6.00am the next morning to determine which of the three different exercise bouts produced the greatest increase in post exercise oxygen consumption.

During the measurement of post exercise VO_2 and BMR, subjects will lie quietly in a supine position in a darkened room for 60 minutes. They will be asked to relax but not to fall asleep. During the last 30 minutes, subjects will again have their expired air measured by the metabolic cart. The post exericse VO_2 and BMR will be calculated from the 30-minute average of the subject's energy expenditure.

After completion of the control session and all three exercise sessions, dependent variables will be analyzed using a

repeated measures analyses of variance. Significance will be accepted at $p<0.05$.

2. HAVE THE RISKS INVOLVED BEEN MINIMIZED AND ARE THEY REASONABLE IN RELATION TO ANTICIPATED BENEFITS OF THE RESEARCH, IF ANY, TO THE SUBJECTS AND THE IMPORTANCE OF THE KNOWLEDGE THAT MAY REASONABLY BE EXPECTED TO RESULT? WHAT PROVISIONS HAVE BEEN MADE TO INSURE THAT APPROPRIATE FACILITIES AND PROFESSIONAL ATTENTION NECESSARY FOR THE HEALTH AND SAFETY OF THE SUBJECTS ARE AVAILABLE AND WILL BE UTILIZED?

The risks will be minimized by using trained technicians and by teaching proper techniques in testing and training of subjects. All technicians will be certified in CPR and First Aid. They will also have extensive knowledge on testing and training procedures. Each subject will complete a health history, smoking, and family history. Subjects will be excluded if they have any condition that may be contraindicated for exercise testing and training.

During maximal oxygen consumption testing and the three training sessions subjects may become fatigued. At least two trained personel will be monitor subjects during their 1-RM test and their resistance exercise session. Heart rate and blood pressure will also be measured during testing.

The risks during measuring body composition using Dexa scan are minimal to a healthy individual and have been approved for use on human subjects. subject will be exposed to a low intensity X-ray which equal to one chest X-ray.

There are minimal risks or discomforts with answering the enclosed questionnaires. Subjects may choose not to complete the questionnaires and will still be able to participate in the study.

For a disinfecting process, saliva and expired air fluids will be thoroughly cleaned from the surfaces and lumen of the respiratory measurement equipment ie. breathing valves,mouthpieces and masks. The devices will be immersed in the CIDEX PLUS solution for at least 20 minutes then will be rinsed and left on a tray to dry. A respiratory tube will be rinsed and hung on a wall until completely dry before reusing.

3. DESCRIBE PROCEDURES TO BE USED TO OBTAIN INFORMED CONSENT. (See attached sample and tips on Informed Consent attached to this application.) ***Attach a copy of the informed consent you will use when submitting this application.*** **ALSO, PLEASE ANSWER THE FOLLOWING:**

(A) WHO WILL BE OBTAINING INFORMED CONSENT?

Informed consent will be obtained by Prawee Sirithienthad

(B) WHEN WILL THE SUBJECTS BE ASKED TO PARTICIPATE AND SIGN THE CONSENT FORM?

Subjects will not be asked to sign the informed consent until they have been screened and cleared for participation. Informed consent will be obtained before any testing occurs.

(C) IN USING CHILDREN, HOW WILL THEIR ASSENT BE OBTAINED? ("Assent" is an additional requirement. Please see attached sample regarding this procedure.)

No children will be used as subjects.

4. DESCRIBE HOW POTENTIAL SUBJECTS FOR THE RESEARCH PROJECT WILL BE RECRUITED.

10 healthy college age male subjects will be recruited from Florida State University and surrounding communities through flyers.

Women are being excluded from this study because of cyclical changes in women's BMR during the ovarian cycle due to the cyclical nature of progesterone.

5. WILL CONFIDENTIALITY OF ALL SUBJECTS BE MAINTAINED? HOW WILL THIS BE ACCOMPLISHED? PLEASE ALSO SPECIFY WHAT WILL BE DONE WITH ALL AUDIO AND/OR VISUAL RECORDINGS, IF APPLICABLE, PICTURES AND PERSONAL DOCUMENTATION OF SUBJECTS BOTH DURING AND AFTER COMPLETION OF THE RESEARCH.

Confidentially will be maintained by assigning each subject a code number and recording all data by code number. The only record with the subject's name and code number will be kept by the principal investigator in a locked drawer in his office. No names, initials, or other identifying characteristics will be reported in publication. Data will be kept for 10 years and then destroyed.

6. IS THE RESEARCH AREA CONTROVERSIAL AND IS THERE A POSSIBILITY YOUR PROJECT WILL GENERATE PUBLIC CONCERN? if SO, PLEASE EXPLAIN.

This research is not controversial and should not generate public concern.

7. DESCRIBE THE PROCEDURE TO BE USED FOR SUBJECT DEBRIEFING AT THE END OF THE PROJECT. IF YOU DO NOT INTEND TO PROVIDE DEBRIEFING, PLEASE EXPLAIN.

Following the completion of the study subjects will be provided with individual reports that will include their data that were collected over the one-year period. A presentation will also be given to describe the findings of the study that they participated in.

Informed Consent Forms MUST contain the following information:

- ***Researcher's name and title of project***
- ***Description of research***
- ***Description of subjects' involvement in the research***
- ***Risks and Benefits to subjects participating in research***
- ***That subjects have the right to not participate or withdraw from participation at anytime without prejudice, penalty or loss of benefits to which otherwise entitled.***

IF AUDIO OR VIDEOTAPING PARTICIPANTS, the following information MUST be included on the Informed Consent:

- ***Purpose of taping and what tapes will be used for***
- ***Where tapes will be stored***
- ***How long tapes will be kept***
- ***When tapes will be destroyed (i.e., Month/Date/Year)***

Example:

Audio or videotaping participants:

I understand that I will be (tape recorded or videotaped) by the researcher. These tapes will be kept by the researcher in a locked filing cabinet. I understand that only the researcher will have access to these tapes and that they will destroyed **by** August 8, 2010.

Samples of additional language for informed consent:

If applicable, the following should be included in your informed consent:

Administering nutritional supplement or other substance to participants:

"allergic reactions are possible from any product and although uncommon, cannot be predicted. You should stop taking the supplement if any rashes, difficulty breathing or other adverse/allergic symptoms occur and seek medical advice"

APPENDIX D

Health Questionaire

HEALTH HISTORY (Long Form)

Name:	
Age:	Sex:
Address:	
Telephone No.(daytime)	(night time)
Current weight	
Personal Physician	
Physician's Address:	

Directions: Please answer the following questions to the best of your knowledge about yourself. Check below any medical condition, treatment or problems that you may have.

I. HEART and CIRCULATORY SYSTEM

A. ____ Heart Attack, Heart disease or any other heart related problems.
B. ____ Heart Valve Problems
C. ____ Heart Murmur
D. ____ Enlarged heart
E. ____ Irregular Heart Beat
F. ____ Atherosclerosis
G. ____ Stroke
H. ____ High Blood Pressure (controlled)
I. ____ High Blood Pressure (uncontrolled)
J. ____ Rheumtic Fever
K. ____ Cardiac Surgery
L. ____ Coronary Bypass
M. ____ High Triglyceride Level
N. ____ High Cholesterol Level
O. ____ Varicose Veins
P. ____ Anemia
Q. ____ Hemophilia
R. ____ Diabetes (controlled)
S. ____ Diabetes (uncontrolled)
T. ____ Phlebitis, Emboli (blood clots)
U. ____ Other, Specify _____

II. RESPIRATORY

A. ____ Emphysema
B. ____ Bronchitis

C. ____ Pneumonia
D. ____ Asthma:____(childhood) ____(currently)
E. ____ Other, Specify_____

III. OTHER DISEASE or AILMENTS

A. ____ Back Injuries/Back Pain
B. ____ Epilepsy/Seizures (past or present)
C. ____ Allergies
D. ____ Liver Disease (Hepatitis, Jaudice)
E. ____ Kidney Disease
F. ____ Arthritis
G. ____ Orthorpedic Leg, Arm or Joint Problems
H. ____ Neurologic Disease
I. ____ Migraine Headache/Other Frequent Headache

Please explain any conditions you checked Yes in I-III above:

_____
_____
_____
_____
_____

IV. HAVE YOU RECENTLY HAD:

A. ____ Chest Pain
B. ____ Shortness of Breath Upon Exertion
C. ____ Heart Palpitations
D. ____ Cough on Exertion
E. ____ Cough Up Blood
F. ____ Swollen, Stiff or Painful Joints
G. ____ Dissiness
H. ____ Lightheadedness
I. ____ Fainting
J. ____ Back Problems
K. ____ Gastrointestinal Disturbances (nausea, vomiting, diarrhea, abdominal pains)

Please explain any conditions you have checked above:

_____
_____
_____
_____
_____

V. FAMILY MEDICAL HISTORY (Immediate Relatives)

A. ____ Heart Attack, Heart Disease or other heart related problems
B. ____ Stroke
C. ____ Atherosclerosis
D. ____ High Blood Pressure

E. ____ Diabetes
F. ____ Lung Disease
G. ____ Respiratory Problems
H. ____ Heart Surgery
I. ____ Heart Related Surgery
J. ____ Other, Specify _____

VI. TOBACO

A. Do you currently smoke or use tobacco products? ____ Yes ____ No
B. What type? ____ Cigarette
____ Pipe
____ Cigar
____ Chewing tobacco
C. How long? ____
D. Amount smoked per day? ____
E. If you do not current smoke, have you ever? ____ Yes ____ No
F. If YES, how long ago did you quit? ____

VII. EXERCISE

A. Do you exercise? ____ Yes ____ No
B. What kind of exercise do you presently engage in?
_____
_____
C. Is your level of effort: ____ minimal ____ moderate ____ high
D. How often do you exercise? ____ days per week
E. How long do you exercise ? ____ minutes per day

Please list any prescription medication, vitamin/nutritional supplements, over-the counter medications you are currently taking or have taken in the last 7 days (don't forget to include, headache/migraine medication, etc.)

_____
_____
_____Please describe your present medical condition and anything we should be aware of concerning your health:
_____
_____
_____
_____

Date of last physical examination? _____ Results_____
Date of last EKG _____ Results _____

I certify that my responses to the foregoing questionaire are true, accurate and complete:

Signature:_____Date:_____

APPENDIX E

Dietary Record Instruction

Instruction:
1.For two days prior to the control session and the day of the control session, it is important that you keep an accurate record of everything you eat and drink. A sheet with complete instructions of how to keep a record of your diet is enclosed. For all three exercise sessions, we will be provideding you with a copy of your records, and will ask you to follow the same diet, so try to eat foods that will be easy for you to replicate.

2. Be sure to include snacks, candy(gum), soft drink etc.
3. Remember to include the preparation of the food eaten (fried, broiled etc.) and some measure of its quality (1 cup of milk, 3 slices of bread, 2 drumsticks, etc.)
4.Remember to record the time of day that you eat/drink all foods.

Food Record Example:

Time	Food	Preparation	Amount
10.00 am	Cereal (Raisin Bran)		8 oz
	2% milk		½ cup
	egg	scrambled	2
2.00 pm	Pizza (Dominos). Sausage & Extra cheese	hand tossed	4 pieces
	Pepsi		1 can

5.You should not exericse 2 days prior to each exercise session.
6.After 6.00pm on each test session day, you should not eat or drink anything except water.
7.For all exercise sessions please have a T-shirt, shorts, and sport shoes to wear.

If you have questions, or need to confirm or change an appointment, please call Prawee at (850) 339-5678

Food Record Form

2 days prior to the control session

Name Date

Time	Food	Preparation	Amount

Food Record Form

1 day prior to the control session

Name Date

Time	Food	Preparation	Amount

Food Record Form

The control session day
Name Date

Time	Food	Preparation	Amount

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BIOGRAPHICAL SKETCH

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