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THE COMBINED THERMIC EFFECT OF FOOD, CONTINUOUS, AND INTERMITTENT EXERCISE

by

Stefan Zander

A thesis submitted in partial fulfillment
of the requirements for the degree of
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in
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THE THERMIC EFFECT OF FOOD, CONTINUOUS, AND INTERMITTENT EXERCISE (111 pp.)

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This summary of five case studies examined the excess post-exercise O_2 consumption (EPOC) after a 45 min exercise period at approximately 70% of $VO_{2max.}$, the EPOC after three 15 min exercise periods at the same intensity, and the thermic effect of a standard liquid meal (10 kcal·kg^{-1} of LBM) in conjunction with the exercise. As a control experiment, five healthy females underwent a 9.5 hour measurement of resting metabolic rate [RMR; $\bar{X}$=.232 l/min (.012)]. Three of the five treatment days were designed to single out: treatment 1: TEM [$\bar{X}$=7.6 l (4.3)], treatment 2: the EPOC after a 45 min running period: EPOC45 [$\bar{X}$=6.9 l (3.4)], and treatment 4: the EPOC after three 15 min running periods spread three hours apart: EPOC3x15 [$\bar{X}$=15.0 l (3.0)]. The other two treatments were combinations of treatments one and two and treatments one and four. Treatment 3: a 45 min running period followed by a meal one hour post-exercise: EPOC45TEM [$\bar{X}$=12.8 l (4.7)] and treatment 5: the combined EPOC and TEM after three 15 min running periods with the meal between period one and two: EPOC3x15TEM [$\bar{X}$=23.6 (9.2)]. Trends toward a greater EPOC in combination with three separate

exercise periods as compared to one single exercise period were observed. There also appeared to be a greater combined EPOC and TEM in conjunction with three exercise periods when compared to the EPOC and TEM after a single exercise period.

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CHAPTER 1
INTRODUCTION

In recent years there has been a great interest in the effect of acute and chronic exercise on resting energy expenditure. Many other factors besides exercise influence the resting metabolic rate (RMR) i.e.: age, gender, body composition, body weight, climate, and time of the year. In addition to the immediate energy cost of exercise, it has been claimed, that the resting metabolic rate stays elevated for several hours after completion of exercise. Depending on the level of this elevation, and how long it persists, this claim is especially attractive to those concerned with weight loss. It has also been reported that exercise may not only influence RMR, but may also affect the thermic effect of a specific meal (TEM).

Daily energy expenditure is made up of adaptive thermogenesis (AT), the thermic effect of exercise (TEE), the thermic effect of food (TEF), and resting metabolic rate (RMR). Together, RMR and TEF make up about 75 - 85% of total daily energy expenditure. Small changes in these two components of daily energy expenditure might result in a significant alteration of energy balance, which could lead to a change in body weight.

Statement of the Problem

The total energy cost of exercise, post-exercise O_2 consumption (EPOC), and a standard liquid meal (TEM) was measured after a single 45 minute exercise period at 70% of $VO_{2max.}$. This was compared to three separate 15 minute exercise periods at the same intensity with the test meal between the first and second exercise period.

Purpose of the Study

This study was designed to answer the following four problems:

1. To measure the thermic effect of a standard liquid meal (TEM) with a caloric content of 10 kcal/kg of lean body mass (LBM).

2. To measure the combined thermic effect of a 45 minute exercise period at 70% of $VO_{2max.}$, the post-exercise oxygen uptake (EPOC), and the thermic effect of a standard liquid meal (see 1. above) ingested 60 minutes after the exercise.

3. To measure the combined thermic effect of three separate 15 min exercise sessions each at 70% of $VO_{2max.}$ and spread three hours apart; the EPOC for each session, and the thermic effect of a standard liquid meal ingested between exercise sessions one and two.

4. To compare 2. and 3. above.

Need for the Study

Exercise is a very popular and significant mode for weight reduction. In individuals who need or want to lose 5 - 25 lbs, exercise is a viable alternative or supplement to caloric restriction. However, obese individuals commonly have difficulties participating in strenuous exercise programs of long duration per session. In obese individuals, weight-bearing exercises, such as jogging, may lead to overuse injuries of, i.e. the knee or the foot. Ultimately, these injuries may result in termination of the exercise program. Current research (Bahr, et al., 1987; Chad & Wenger, 1988) suggests, that aerobic exercise of at least 20-30 min duration at an intensity of >70% $VO_{2max.}$ results in a significant excess post-exercise oxygen consumption (EPOC). This research has focused on single bouts of exercise and its effect on EPOC. The literature does not give any information about the effect on EPOC of three relatively short bouts of exercise participated in throughout a day. A possible constant elevation of RMR throughout the day caused by exercise bouts in the morning, at noon, and in the afternoon could have a positive impact on weight reduction regimens, especially if each exercise bout would potentiate the thermic effect of the following meal. The latter has been suggested in the literature (Nichols, et al., 1988, Maehlum, et al., 1986, Segal & Gutin, 1983).

Limitations

In every study there are certain unavoidable limitations and assumptions, and the following are the major ones:

1. Subjects were instructed to refrain from eating for 12 hours prior to each experiment and to refrain from strenuous exercise for 36 hours prior to each experiment. It was assumed that this regime was adhered to. Subjects were asked whether they had complied with this request, and were only tested if they had followed instructions.

2. Subjects were asked to maintain their normal diets throughout the testing period.

3. During pretesting to determine $VO_{2max.}$, it was assumed that all subjects performed maximally.

4. The major limitation of this study is that any inference from the results of the study to the total population is improper. The sample size in this study was very small (N = 5).

5. The subjects tested in this study were probably more aerobically fit than the overweight or average person that might ultimately benefit from the potential findings of this study.

Definition and Explanation of Terms

Resting metabolic rate (RMR) is the largest component of daily energy expenditure. It is the amount of energy expended while resting quietly in a comfortable environment in a postabsorptive state. RMR can be considered as the metabolic cost of maintaining the integrated systems of the body at rest in a thermoneutral zone.

Basal metabolic rate (BMR) is the amount of energy expended while resting quietly in a comfortable environment. It is usually measured early in the morning prior to any physical activity and at the longest interval from previous meals. The BMR is typically slightly lower than RMR.

Thermic effect of exercise (TEE), also called thermic effect of physical activity (TEA), is the second largest component of daily energy expenditure and also the most variable component of RMR in humans. TEA or TEE accounts for the additional energy expended above RMR and TEF and includes all physical activity, shivering and fidgeting, as well as purposeful physical exercise.

The thermic effect of food (TEF), also called dietary induced thermogenesis or specific dynamic action of food, includes the cumulative energy expenditure associated with the ingestion, digestion, and absorption of food.

The thermic effect of a test meal (TEM) is the increased energy expenditure above RMR after a specific standard test meal is ingested; This includes the energy cost of digestion, absorption, metabolism, and storage within the body. TEM can be divided into two components:

> Obligatory thermogenesis is the energy cost associated with absorption and transport of nutrients, as well as the synthesis of fat, protein, and carbohydrate.
>
> Facultative thermogenesis represents a dissipation of energy which cannot be accounted for by obligatory processes (Acheson, et al., 1983). A sympathetic-mediated activation of brown adipose tissue (BAT) has been shown in animals, but there is no convincing evidence that this tissue is functional in humans (Jequier, 1986).

Adaptive thermogenesis (AT) is defined as the oxygen or caloric cost of adaptation to environmental stresses such as changes in ambient temperature, emotional stress, or other factors. This is a part of total RMR.

Open circuit spirometry is one of the two methods of indirect calorimetry. It measures the amount of O_2 or energy used. The subject breathes atmospheric air and their expired air is analyzed for volume, O_2, and CO_2 concentration. O_2 used can be calculated and caloric cost can be determined.

Respiratory Quotient (RQ) is the ratio of CO_2 produced to the amount of O_2 consumed. It serves as a convenient guide to the nutrient mixture being catabolized for energy. RQ only exists at the cell level, and ranges from .7 (RQ for fat) to 1.0 (RQ for carbohydrate).

Respiratory exchange ratio (R or RER) is the ratio of CO_2 produced to O_2 consumed when the exchange of O_2 and CO_2 in the lungs no longer reflects the oxidation of specific foods at the cellular level. For example, an increase in CO_2 elimination occurs during hyperventilation even though the increased elimination is not accompanied by a corresponding increase in O_2 consumption. R and RQ are calculated in the same way.

Excess post-exercise oxygen consumption (EPOC) is the elevation of O_2 consumption above RMR after cessation of exercise. The magnitude of this extra oxygen consumption, which has been previously known as "oxygen debt", or "recovery oxygen", is mainly dependent on the intensity and duration of the preceding exercise (Poehlman, 1989).

CHAPTER 2
REVIEW OF THE RELATED LITERATURE

Introduction

The human body depends on the conversion of chemical energy to other forms of energy. These conversions are limited by the first law of thermodynamics: when mechanical energy is transformed into heat energy, or heat energy is changed into mechanical energy, the ratio is a constant quantity (the principle of the conservation of energy). Historically, Robert Mayer, in 1842, first originated the idea of a general principle of conservation of energy (Fong, 1963).

Approximately 60 - 75% of daily energy expenditure can be accounted for by resting metabolism. The remainder of daily caloric expenditure is muscle activity and the catabolism of food. The measurement of energy expenditure is referred to as calorimetry, a process in which energy is measured as heat. Calorimetry is based on the law of conservation of energy. Calorimetry, as applied to studies in humans, is divided into direct and indirect calorimetry. Direct calorimetry is the measurement of energy expenditure in the form of heat; all types of energy are converted to heat and then measured. During indirect calorimetry, energy expenditure is determined from the amounts of O_2 used and the subsequent CO_2 produced (Consolazio, et al., 1963).

History of Calorimetry

Energy expenditure was first measured by direct calorimetry in 1761 by Joseph Black, who measured heat production which caused ice to melt (Bogert, et al., 1973). In 1780, Lavoisier was able to calculate the amount of heat produced by an animal by knowing the quantity of heat required to melt a given quantity of ice. Lavoisier's device was also a direct calorimeter because it determined metabolism by measuring heat produced. In 1784, Lavoisier conducted experiments with a respirometer and established that something in the air (oxygen) was consumed by the animal and that something else (carbon dioxide) was produced in approximately equal amounts (Lavoisier & La Place, 1789). Today his system is referred to as a closed-circuit, indirect calorimeter. In 1892, Haldane first used an open-circuit, indirect calorimeter. In his experiment, an animal breathed room air, and the expired air was analyzed for CO_2 content.

Atwater and Benedict (1903) applied the techniques of direct and indirect calorimetry to demonstrate the validity of the law of conservation of energy for the human organism. They first used carbon dioxide production as a measure of gaseous exchange, and later used oxygen consumption (Benedict & Milner, 1907). Comparative studies of the direct and indirect methods showed an agreement within 0.17% of each method over an RQ range between 0.77 and 0.97 (Gephart & DuBois, 1915). Following these studies, the accuracy of both direct and indirect calorimetry became widely accepted.

Methods of Measuring the Body's Heat Production

Direct Calorimetry. The human calorimeter is a box-like chamber containing multiple-layer walls designed to insulate the chamber from the environment and to measure heat production. Heat production was measured by the increase in temperature of cold water flowing at a constant rate through tubes coiled near the ceiling of the chamber. An increase in temperature of 1°C per kilogram (liter) of water is equivalent to 1 kcal of energy (McArdle, et al., 1986). Because of the physical limits, the techniques of direct calorimetry, although highly accurate and of great theoretical importance, are impractical for studies of human energy expenditure during various sport, recreational, and occupational activities (McArdle, et al.,1986). Human calorimeters are very useful in measuring RMR over extended periods of time (up to several days), since the subject can carry out normal daily activities within the chamber.

Indirect Calorimetry. All human energy metabolism ultimately depends on the utilization of oxygen. In measuring energy expenditure indirectly, the known proportionality between the oxygen consumption and carbon dioxide production and the total energy expenditure is used (Consolazio, et al., 1963).

Energy expenditure can be measured by either closed - or open-circuit spirometry. Benedict in 1918 and Krogh in 1923 originally proposed the closed-circuit method for measuring basal metabolic rate (Consolazio, et al., 1963). In the closed circuit method, the

subject breathes pure oxygen from a spirometer and the expired O_2 returnes to the spirometer, after the CO_2 has been removed. The amount of oxygen used is equal to the amount that is taken from the spirometer (McArdle, et al., 1981).

In the open-circuit method, the subject breathes room air. The expired air runs through a gas meter, and is later analyzed for O_2 and CO_2. The difference in composition between the exhaled air and the ambient air reflects the body's constant release of energy.

The two traditional methods for open-circuit spirometry make use of either a light-weight portable spirometer (Kofranyi-Michaelis meter, K-M meter), that is worn during an activity, or the "Douglas bag" or "balloon method", which is routinely used to collect expired air under laboratory conditions (McArdle, et al., 1986). A small gas sample (500 - 1000 ml) is taken from the bag or balloon for O_2 and CO_2 analysis. Corrections to the volume are made to standardize the temperature, pressure, and saturation (Consolazio, et al., 1963).
The K-M meter was developed in Germany in the 1940s for field studies. It can be strapped to a subject's back to measure the volume of air exhaled, while at the same time taking a small sample of that air. The K-M meter was widely used for measuring energy expenditure in low and medium intensity field activities. The expired air samples were analyzed using either manual Haldane, or Micro Scholander gas analyzers, or automated electronic gas analyzers. The Haldane procedure (Haldane & Priestly, 1935) measured the gas volume from a calibrated burette, and determined O_2 and CO_2 content by separating the chemical absorption of O_2 and CO_2. Scholander (1947) utilized the same principles as Haldane using

a calibrated micrometer as a measuring device (Consolazio, et al., 1963).

Today, oxygen consumption is measured predominantly with computerized systems integrating a paramagnetic O_2 and infrared CO_2 analyzer, gas meter, thermometer, and barometer. Information from the different components of the system is loaded continuously into a computer with programmed software which computes O_2 consumption and CO_2 production and prints out several respiratory and metabolic parameters. Despite the speed and accuracy of today's computerized systems, both Haldane and Scholander analyzers are considered standard instruments for the analysis of calibrating gases.

Physiology of Metabolic Regulation

The thyroid gland secretes two hormones; thyroxine (T4) and triiodothyronine (T3), which play an essential role in the regulation of metabolic rate. About 90% of the hormone secreted by the thyroid gland is T4, while only approximately 10% is T3. Part of the T4 is converted to T3 in the blood and the peripheral tissues. Both hormones have the same function, but T3 is more biologically active than T4 (Hadley, 1988).

The thyroid hormones have two major physiological effects, one of which is significant to the context of this study: an increase in the overall metabolic rate. The thyroid hormones increase the metabolic activity of almost all tissues, with only a few exceptions

(brain, retina, spleen, testes, and lungs). Excessive quantities of thyroid hormones can increase basal metabolic rate by as much as 60 - 100%. Conversely, if thyroid hormone production is stopped, basal metabolic rate drops between 30 - 45%. The most likely basic function of thyroid hormones is their ability to activate the DNA transcription process in the cell nucleus, with the resulting formation of many new cellular proteins (Guyton, 1986).

To maintain regular levels of metabolism, precisely the right amount of thyroid hormone must be secreted at all times. A feedback mechanism which operates through the hypothalamus and anterior pituitary gland controls the rate of thyroid secretion. Thyroid stimulating hormone (TSH), also known as thyrotropin, is an anterior pituitary hormone which increases the secretion of T3 and T4 by the thyroid gland. Electric stimulation of multiple areas of the hypothalamus increases the anterior pituitary secretion of TSH and also increases thyroid gland activity. Anterior pituitary secretion is controlled by a hypothalamic hormone, thyrotropin-releasing hormone (TRH), which is secreted by nerve endings in a specific part of the hypothalamus. From there it is transported to the anterior pituitary gland, which in turn regulates the thyroid gland (Guyton, 1986).

Factors Affecting Resting Metabolism

Age. There is a change in resting metabolic rate throughout life. Children have a very high RMR in relation to their size. Their RMR is almost twice that of an old person (60-80 yrs.). There are

conflicting reports on the decrease of RMR over the course of adulthood. Calloway and Zanni (1980) measured men between 63 and 77 years of age and found their resting metabolic rate was 13% lower than that of younger subjects with a mean age of 28 years. Owen (1988) to the contrary, reported that in mentally and physically active men and women who have normal brain, liver, and muscle function, there seems to be no significant influence of age on RMR. Resting metabolism lowers because older people are often less active and sometimes disabled (Bogert, et al., 1973).

Gender and Body Composition. In females, resting metabolic rates are about 5 - 10% lower than in males. The difference can mostly be explained by the difference in body composition, since fat is less metabolically active than muscle, and women have more fat than men (McArdle, et al., 1986). Ravussin et al. (1986) reported that fat-free mass is the best available determinant of 24 hour energy expenditure and explains 81% of the variance observed between individuals. RMR expressed per kilogram of fat-free mass is almost identical in males and females.

Body Size. Resting metabolism is a function of body size. A larger (height and weight) individual needs more oxygen than a smaller one. These differences can be accounted for by either dividing oxygen uptake by body surface area (Du Bois & Du Bois, 1915) or by dividing O_2 uptake by body weight. Nomograms have been developed to determine body surface area. RMR and BMR can be predicted from body surface area (Boothby, et al., 1936, Carpenter, 1948, and Katch & McArdle, 1983). These nomograms, which estimate RMR are not commonly used today because they tend to

greatly overpredict energy requirements in young people and underpredict in the elderly.

Hormones. As described earlier in this chapter (Physiology of Metabolic Regulation), the thyroid gland regulates the body's metabolism through the secretion of thyroxine (T4) and triiodothyronine (T3). Other hormones that influence RMR are testosterone and growth hormone. Testosterone can increase the BMR about 10 - 15%, and growth hormone can increase BMR as much as 15 - 20% as a result of direct stimulation of cellular metabolism (Guyton, 1986).

Environmental Temperature and Seasonal Variations. Humans are homeotherms, which means they maintain a constant core temperature over a wide range of ambient temperatures. The heat regulating centers in the hypothalamus keep the body at approximately 37°C. Different physiological responses occur at low and high temperatures. At low temperatures (outside the thermoneutral zone), oxygen consumption increases in an effort to produce enough heat to maintain core temperature. The extra heat that is needed is generated through shivering. At high temperatures, oxygen consumption increases due to elevations in core temperature (Consolazio, et al., 1963). Adaptations of metabolic rate to seasonal variations in temperature were studied by Gustafson and Benedict at Wellesly College in 1928. In twenty women they found RMR to be lower in the winter than in the spring.

Diet (Fasting, Malnutrition, and Overfeeding). Resting metabolism seems to be affected by fasting or overfeeding if it persists for multiple days. Lammert and Hansen (1982) showed a

significant increase in RMR after a two-week period of overfeeding. The results, however, were highly individual. Lammert and Hansen also showed a decrease in RMR after a two-week period of underfeeding. Garby and Lammert (1977) found no significant effect of the preceding day's energy intake on the oxygen consumption during rest and during exercise before and after a test meal. Prolonged malnutrition can decrease the metabolic rate as much as 20 - 30%. This decrease is presumably caused by paucity of the necessary food substances in the cells (Guyton, 1986).

Physical Activity and Exercise. Metabolic rate is dramatically affected by strenuous exercise. Single maximal prolonged exercise periods can increase the overall heat production of the body to about twenty times in trained athletes. Short bursts of exercise can liberate as much as 100 times the normal resting amount of heat in any single muscle (Guyton, 1986).

Fever and Sickness. Fever is a pathological condition in which there is an abnormal rise in body temperature. Fever increases resting metabolism because of the increase of speed in chemical reactions which is termed the Q10 effect (Gaesser & Brooks, 1984). There is an increase in speed of about 120% for every 10°C rise in temperature.

Psychological Factors and Sleep. Morgan (1985) in a review on psychogenic factors and exercise, states that oxygen uptake is known to increase as the subject gets "excited" and decreases as he or she becomes "relaxed". An individual's thoughts (cognition), feelings (affect), and sensations (perception) can independently or in

concert influence metabolism (Morgan,1983, Morgan, 1983, and Suess, et al., 1980). During sleep, metabolic rate decreases about 10 - 15%. This is probably due to at least two factors: a decreased tone of skeletal muscle, and a decreased activity of the sympathetic nervous system (Guyton, 1986).

Thermic Effect of a Meal/Food on RMR

The stimulating effect of food on energy expenditure was observed over a century ago by Rubner (1902), who named it specific dynamic action (SDA). It was believed that protein was the sole nutrient causing an increase in energy expenditure. SDA was originally thought to be related to the process of digesting and absorbing nutrients. However, subsequent studies revealed comparable effects when nutrients were administered by vein (Burzstein, et al., 1989). Although the TEF can vary between individuals, on average it accounts for an energy expenditure of approximately 10% of caloric intake (Danforth, 1985).

TEF can be explained largely by the energy required for the digestion, absorption, transport, metabolism, and storage of the ingested food. Other factors, such as the activation of the sympathetic nervous system by carbohydrates or other dietary components also can contribute significantly to the thermic response (Woo, et al., 1985). The time course of the increase in metabolic rate above control levels associated with meals of carbohydrate (glucose) is different from that for fat meals, which is different for protein meals. With a protein meal, the peak response is about 1.5 to 2.0

hours after the meal, and metabolic rate does not return to baseline levels for several hours. After a glucose meal, metabolic rate rises to a peak at about 45 min, and is declining again by two hours after the meal. After a fat meal, the increase in metabolic rate is small and gradual, with no clearly defined peak (Garrow, 1986).

TEM is highly correlated to caloric intake. D'Alessio, et al. (1988) showed that TEF was not correlated with weight, fat-free mass, or fat mass. From their study, Segal et al. (1985) concluded that for men of similar total body weight and Body Mass Index, body composition is a significant determinant of postprandial thermogenesis. The responses of obese people are significantly reduced compared with those of lean men (Segal et al., 1985).

Effect of Chronic Exercise on RMR

Resting metabolic rate is strongly correlated with fat-free mass (FFM) and body weight. This explains why obese people are generally characterized by a higher absolute level of RMR, this difference disappearing when RMR is expressed per unit of FFM (Ravussin, et al., 1982).

There is conflicting evidence about the influence of chronic exercise on RMR. While some studies (Tremblay, et al., 1986, LeBlanc, et al., 1985, Poehlman, et al., 1988, Poehlman, et al., 1989) suggest that trained individuals have a higher resting energy expenditure when compared to untrained individuals, other studies have found no difference in RMR between trained and untrained subjects (Hill, et al., 1984, LeBlanc, et al., 1984, Trembley, et al., 1983, Poehlman, et

al., 1985). Poehlman et al. (1989) stated that the lack of concordant results among studies could be due to several methodological factors including the following:

1. Failure to examine a wide range of fitness levels; most studies have classified subjects into two discrete fitness groups (i.e. trained and untrained).
2. The use of different criteria to define trained and untrained individuals.
3. Insufficient sample size to detect differences in RMR and TEM among individuals varying in aerobic fitness.

Effect of Exercise Training on TEM

Some investigators have found TEM to be increased with improved fitness (Davis, et al., 1983; Hill, et al., 1984), whereas other investigators have reported an inverse relationship (Poehlman, et al., 1988, Tremblay, et al., 1985, LeBlanc, et al., 1984, Poehlman, et al., 1985, Tremblay, et al., 1983). Poehlman (1989) found a significant curvilinear relationship between $VO_{2max.}$ and TEM in a group of 28 young males, indicating that a higher TEM was noted in the mid-range of $VO_{2max.}$ values, whereas a lower TEM was observed at the extremes (low and high) of $VO_{2max.}$. A similar relationship was obtained when TEM was adjusted for FFM.

Trembley, et al. (1983) found a significant correlation between TEM and postprandial respiratory quotient after consumption of a 1600 kcal mixed meal in eight trained and eight untrained males. Their major conclusion was that exercise training exerted a sparing

effect on postprandial energy expenditure, and that this effect was associated with a relatively greater lipid oxidation in trained men at rest.

LeBlanc et al. (1984) reported a reduced TEM (818 kcal mixed meal) for the first 60 min postprandial period in exercise trained female subjects when compared with untrained subjects. They did, however, not find any differences in TEM between the two groups over the total 2 hour postprandial measuring period. It was speculated that trained females shunted more of the nutrients to replete glycogen reserves, at least during the first 60 min postprandial. Owen (1986) also found no difference in the overall 4 hour TEM between athletic and nonathletic females. Poehlman, in his 1989, review noted that at present there is no convincing evidence that exercise training alters the magnitude of TEM in females.

Post-Exercise Heart Rate and Rectal Temperature

The immediate recovery of heart rate and rectal temperature following exercise is well established (Åstrand, 1977). True resting heart rates are extremely difficult to obtain before and after exercise. Immediately following exercise, heart rate, as well as rectal temperature rapidly drop at first, then drop gradually until they reach a resting state (Bahr, et al., 1987 & Maehlum et al., 1986).

The time required for heart rate to return to resting levels depends on the intensity of the exercise period, the fitness level of the individual, and environmental conditions. For a given duration and

intensity of exercise, body temperature increases are less in trained men than in untrained men (Morehouse & Miller, 1963)

Excess Post-Exercise Oxygen Consumption (EPOC)

The frequently asked question when investigating the effects of acute exercise on post-exercise metabolism is whether the elevated post-exercise energy expenditure significantly contributes to total energy expenditure. In other words, is the EPOC of practical significance for weight control?

Early studies from several groups of investigators on the effects of acute exercise on EPOC tried to define the time course as well as the cause of the post-exercise increase in metabolic rate (Benedict & Sherman, 1937, Edwards, et al., 1935, Schneider & Foster, 1931). In these studies, food intake was not controlled; therefore the observed elevation in metabolic rate until 24 - 48 hours post-exercise can probably for the biggest part be attributed to the thermic effect of the meals taken in during the recovery period.

In one of these early studies, Edwards et al. (1935) observed a 25% elevation in metabolic rate in three male athletes for 15 hours following 2 hours of strenuous football and a 10% increase for 48 hours following other heavy exercise. Other studies that have reported sustained increases in metabolic rate include Maehlum, et al., 1986, Bielinski, et al., 1985, Passmore & Johnson, 1960, Bahr, et al., 1987, and Devlin, et al., 1986).

Bahr et al. (1987) found an increase in O_2 consumption for 12 hours post-exercise after 20, 40, and 80 min of cycling at 70% of

$VO_{2max.}$. The magnitude of 12 hour EPOC was proportional to exercise duration and, on the average, equaled 15.2% of total exercise O_2 consumption.

Maehlum et al. (1986) studied four males and four females after an average of 80 min of cycle exercise at 70% of $VO_{2max.}$. Oxygen uptake at each time point in each subject was greater for 12 hours post-exercise when compared with the control experiment.

Subjects in a study by Bielinski et al. (1985) walked at a mean intensity of 50% of $VO_{2max.}$ for three hours. Metabolic rate had returned almost to normal six hours after exercise, but was significantly elevated the following morning, 18 hours post-exercise. In 1960, Passmore and Johnson found a 14 - 18% elevation in metabolic rate for seven hours after walking 16 km at 6.4 km/h.

Several investigators (Brehm & Gutin, 1986, Freedman-Akabas, et al., 1985, Pacy, et al., 1985, Henson,et al., 1987, Dallosso & James, 1984, Elliot, et al., 1988) have reported a rapid decline of metabolic rate to resting levels after exercise (Poehlman, et al., 1989). Brehm and Gutin (1986) examined the effects of intensity, mode of exercise, and aerobic fitness on EPOC. Eight runners and eight sedentary adults completed 3.2 km of walking or running each session. Their recovery energy expenditure only amounted to 3 - 17 kcal.

Another study that failed to show a prolonged thermogenic effect of moderate exercise was conducted by Pacy et al. (1985). Exercise was performed at a constant rate on a cycle ergometer during the initial 20 min of four successive hours. There was a significant elevation of mean oxygen uptake during 40 min post-exercise by

13.6%. Sixty minutes after ceasing exercise, mean O_2 uptake was not different from pre-exercise levels.

In 1985, Akabas et al. studied the effect of 20 min of exercise at an intensity eliciting approximately anaerobic threshold, on EPOC. Twenty-three subjects showed no significant elevation of VO_2 above the resting level, from 40 min to three hours after exercise. Akabas et al. concluded, that no appreciable caloric loss, beyond that generated by the exercise period itself and the early recovery phase, is found in either fit or unfit subjects.

The removal and conversion of lactate and the replenishment of oxygen stores immediately following exercise was thought to be the reason for EPOC. The elevation of O_2 uptake immediately following exercise was termed oxygen debt by Hill in 1924 (Hill, 1924). Lactate removal after maximal exercise of short duration is completed within 60 - 90 minutes after exercise. Therefore it is unlikely that lactate removal can account for the increased oxygen uptake observed several hours after the end of exercise. Moreover, during prolonged exercise at 75% of maximal oxygen uptake, blood lactate concentrations are much lower than those observed at maximal exercise (Hermansen, et al., 1984). Today it is generally accepted that lactate removal only accounts for a small fraction of EPOC.

Devlin et al. (1986) described another possible mechanism underlying EPOC. They associated the increased metabolism after exercise with an increase in nonoxidative glucose disposal and a decrease in carbohydrate oxidation. Glycogen synthetase was increased after exercise. Poehlman (1989) concluded from Devlin's

findings that the increase in post-exercise metabolic rate may be related to the energy cost of replenishing glycogen stores.

In 1984, Gaesser and Brooks described the role of increased levels of catecholamine and other hormones as contributors to EPOC. Other reports (Kaerki, 1956 & Maron et al., 1977) have also indicated elevated catecholamine levels in blood for many hours after heavy work or exercise. Maron et al. reported increased levels of adrenaline for 72 hours after marathon running.

Gaesser and Brooks (1984) also showed the influence of an increased body temperature (Q 10 effect) for >one - two hours post-exercise. This prolonged increase in body temperature was not confirmed by Bahr et al. (1987), Maehlum, et al. (1986), and Brehm and Gutin (1986). Rectal temperatures in those studies had returned to resting levels by approximately 30 minutes post-exercise.

Summary

There are several ways of assessing an individual's energy expenditure, including direct and indirect calorimetry. Indirect calorimetry can be divided into open and closed circuit spirometry. Multiple factors can affect resting metabolism, including diet, hormones, fever, and environmental temperature. When measuring small changes in RMR, as in the case of EPOC, great care has to be taken to control these factors.

There is conflicting evidence about the effect of chronic and acute exercise on RMR. While some studies report a sustained elevation of RMR of up to 24 hours, others fail to show an elevation

of even 30 min. Most of these differences can be attributed to the different mode, intensity, and duration of the activity. Methodological differences also seem to account for many of the discrepancies between studies. It appears, that if exercise is to significantly enhance post-exercise energy expenditure, the exercise has to be intense and prolonged.

CHAPTER 3

METHODOLOGY

Five apparently healthy female subjects, between the ages of 22 and 33 years [$\bar{X}$=26.2 (4.4)] volunteered for this study. All were above average fitness level, but not highly trained [$VO_{2max.}$= 51.7 $ml \cdot kg^{-1} min^{-1}$ (7.8)]. They were weight-stable (±5 lbs) for at least one year prior to the study. Their caloric intake (see Table1) was estimated through dietary records on two weekdays and one weekend day (Segal & Gutin, 1983) (see Appendix B). The subjects' body composition ranged from 17 - 28% fat [$\bar{X}$=22.4% (4.7)]. Physical and physiological characteristics are also presented in Table 1.

Table 1

Physical and Physiological Characteristics and Average Daily Caloric Intake of Subjects

Subject#	Age	Height (cm)	Weight (KG)	% Fat	LBM (KG)
1	22	178	72	22.7	55.7
2	23	165	58	25.6	43.9
3	25	162	62	28.2	44.5
4	28	157	51	18.1	41
5	33	169	55	17.3	44.7
Mean	26.2	166.2	59.6	22.38	45.96
SD	4.44	7.92	8.02	4.70	5.64

Subject#	VO2max (l/min)	VO2max (ml/kg/min)	Kcal Intake/day
1	3.87	54.57	1054
2	2.77	47.74	689
3	2.74	44.24	947
4	3.2	63.99	1349
5	2.73	47.87	1194
Mean	3.06	51.68	1046.6
SD	0.49	7.83	250.51

When compared to national norms for similar age groups, subjects' body composition ranged from the 30th to 90th percentile (Golding, et al., 1989). Subject 4, although not trained for any specific athletic event, had a very high maximum oxygen uptake (63.99 $ml \cdot kg^{-1} \cdot min^{-1}$). Subject 1, at 178 cm, 72 kg weight, and 55.7 kg LBM, was much larger than other subjects. Her weight and LBM were 12/11 kg larger than the group's mean.

Experimental Design

The risks and benefits of the study were explained to each subject in an informed consent form (Appendix A). Subjects completed a series of pre-tests for descriptive purposes. These tests included a weight - diet - and exercise history (Appendix B), as well as a maximal cardiorespiratory fitness test (explained later). The exercise history questioned current and past exercise habits (especially aerobic exercise). Subjects were hydrostatically weighed to determine density and percent body fat (Appendix C). Subjects were given instructions regarding exercise and eating prior to each experimental period (Appendix D). They were asked to refrain from strenuous exercise for 36 hours prior to each experimental period and from eating for 12 hours prior to each period. Testing required a total of six nonconsecutive days within a two week period. All experiments were performed during the subjects' postovulatory period. On the morning of each treatment day, subjects filled out a questionnaire concerning the last food intake, sleep, stress, medication, and menstrual cycle (Appendix E).

Control Day: The control day consisted of a nine hour RMR measurement. Although this was part of another project being performed by the laboratory, the information was essential for use as baseline data. It was used to explain diurnal and random biological fluctuations in RMR, as well as errors of measurement. Two VO_2 measurements were performed at 7:30 and 7:45 am to familiarize the subject with the measurement procedure. Starting at 8:00 am, 5 minute VO_2 measurements were performed every half hour for 9 hours, until 5:00 pm.

The following five treatment days were conducted at the convenience of the subjects' schedules (see Figure 1):

Treatment 1: Thermic effect of a standard meal (TEM).

Treatment 2: Thermic effect of a 45 minute exercise period and its EPOC (EPOC 45).

Treatment 3: Thermic effect of a 45 minute exercise period and its EPOC preceding a standard meal (EPOC 45 + TEM).

Treatment 4: Thermic effect of three 15 minute exercise periods and their EPOC (EPOC 3x15).

Treatment 5: Thermic effect of three 15 minute exercise periods and their EPOC with a standard meal between period one and two (EPOC 3x15 + TEM).

Data Collection Sequence

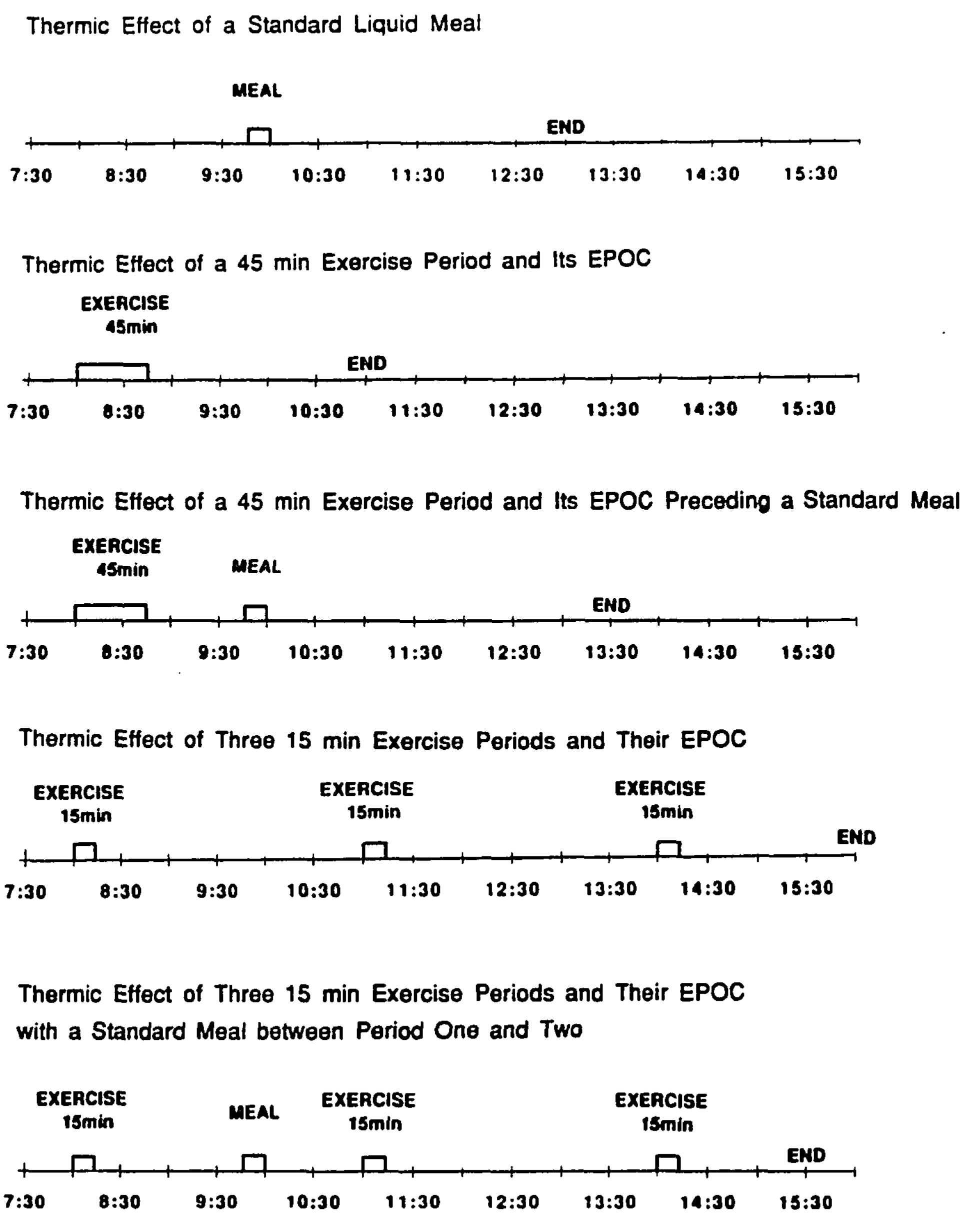
Pre-test Procedures:

1. Informed written consent was obtained (Appendix A).

2. A registered dietitian (RD) conducted a personal interview with each subject to determine a weight and exercise history (Appendix B).

Figure 1

Schedule of Events - Treatment Days 1 - 5



3. The RD instructed subjects how to keep dietary records for two weekdays and one weekend day in order to estimate average daily caloric intake (Appendix B).

4. A maximal graded treadmill test was performed to determine maximal oxygen uptake (see Maximal Oxygen Uptake). The test was performed to voluntary exhaustion or to criteria for reaching maximal oxygen uptake.

5. Hydrostatic weighing and residual volume measurements were performed to determine each subject's percent body fat.

General Procedures:

1. On each morning of testing, subjects were driven to the laboratory after a good nights rest, a 12 hour fast, and a 36 hour abstinence from strenuous exercise. They reclined on a sofa during the entire experiment, and were allowed to read, write or watch television in a seated or reclined position. During rest periods, between exercise and/or eating, they were not allowed to sleep, stand, or walk around the laboratory.

2. Subjects were weighed each day prior to testing.

3. Barometric pressure (Pb), room temperature (Ta) and relative humidity (RH) were measured and recorded each morning before testing.

4. Oxygen uptake was measured with a calibrated Vacumed integrated metabolic system (see instructions in Appendix F) at 7:30-7:35 and 7:45-7:50 am. Heart rates were recorded with a Vantage Heart rate monitor every minute during the collection periods. Other measurements collected or calculated include: VE, RQ,

tidal volume (TV), respiration rate (RR), and METs. VO_2 and HR values for the last three minutes of each collection period were averaged. The 7:30 and 7:45 am collection periods served two purposes:

a. To accustom the subject to the system.

b. To ensure that the subject was in a resting state prior to each experiment.

During treatments 2-6, at least one of the two pre-test VO_2 measurements had to fall within one standard deviation of the subject's mean RMR or the subject was rescheduled for a different day.

Experimental Periods 1-5

Control Day: Resting metabolic rate (RMR)

Starting at 8:00 am, five minute VO_2 and HR measurements were taken in 30 minute intervals until 5:00 pm. VE, RQ, TV, and RR were also taken in 30 minute intervals. Subjects periodically were reminded to stay as calm as possible.

The following five treatment days are described below:

Treatment 1: Thermic effect of a standard meal (TEM)

The same procedures as described above were used until 9:30 am. At 9:50 am, the subject consumed a liquid meal [Ensure Plus, Ross Laboratories; 53.3% CHO, 32% fat, and 14.7% protein; mean caloric content: 460 kcal (56)] with a caloric content of 10 kilocalories per kilogram of lean body mass. Subjects had 10 minutes to ingest the drink. Starting at 10:00 am, five minute VO_2 and HR measurements

were taken in 15 minute intervals for 1.5 hours postprandially. At 11:30 am, 30 minute measurements resumed until two consecutive VO_2 measurements were within one standard deviation of resting values (control day) for the same time of day.

Treatment 2: Thermic effect of a 45 minute exercise period at 70% of $VO_{2max.}$ and its EPOC (EPOC 45)

The procedures outlined for the control day were followed until 8:00 am. At 8:00 am, the subject started a 45 minute treadmill run at an intensity eliciting approximately 70% of $VO_{2max.}$. Metabolic calculations of VO_2, TV, VE, RQ, RR, METs, as well as HR were taken for five minutes at the beginning of the run (8:00 am), 15 minutes later at 8:20 am, and again 15 minutes later at 8:40 am. Immediately upon completion of the exercise at 8:45 am, post-exercise measurements were started; the subject recovered while seated on a chair that was placed on the treadmill belt. The same metabolic measurements were taken for five minutes in 15 minute intervals for 1.5 hours post-exercise. At 10:30 am, if MR had not returned to baseline levels, 30 minute measurements resumed until two consecutive VO_2 measurements were within one standard deviation of resting values for the same time of day.

Treatment 3: Thermic effect of a 45 minute exercise period at approximately 70% of $VO_{2max.}$ and its EPOC followed by a standard meal (EPOC 45 & TEM)

The procedures outlined for the control day were followed until 8:00 am. At 8:00 am, the subject started a 45 minute treadmill run at an

intensity eliciting approximately 70% of $VO_{2max.}$. Metabolic calculations of VO_2, TV, VE, RQ, RR, METs, as well as HR were taken for five minutes at the beginning of the run (8:00 am), 15 minutes later at 8:20 am, and again 15 minutes later at 8:40 am. Immediately upon completion of the exercise at 8:45 am, post-exercise measurements were started; the subject recovered while seated on a chair that was placed on the treadmill belt. The same metabolic measurements were taken until 9:45 am. At 9:50 am the subject consumed a liquid meal [Ensure Plus, Ross Laboratories; 53.3% CHO, 32% fat, and 14.7% protein $\overline{X}$=460 kcal (56)] with a caloric content of 10 kilocalories per kilogram of lean body mass. Subjects had 10 minutes to ingest the drink. Starting at 10:00 am, five minute VO_2 and HR measurements were taken in 15 minute intervals for 1.5 hours postprandially. At 11:30 am, 30 minute measurements resumed until two consecutive VO_2 measurements were within one standard deviation of resting values for the same time of day.

Treatment 4: Thermic effect of three 15 minute exercise periods at approximately 70% of $VO_{2max.}$ and their EPOC (EPOC 3x15)

The procedures outlined for the control day were followed until 8:00 am. At 8:00 am, the subject started a 15 minute treadmill run at an intensity eliciting approximately 70% of $VO_{2max.}$. Metabolic calculations of VO_2, TV, VE, RQ, RR, METs, as well as HR were taken for five minutes at the beginning of the run (8:00 am) and for the last five minutes of the run (8:10 am). Immediately upon completion of the exercise at 8:15 am, post-exercise measurements were started; the subject recovered while seated on a chair that was placed on the

treadmill belt. The same metabolic measurements were taken for five minutes in 15 minute intervals for 1.25 hours post-exercise. Starting at 9:30 am, measurements were again taken in 30 minute intervals. A second 15 minute run was performed at 11:00 am and a third one at 2:00 pm. Metabolic measurements were taken for five minutes in 15 minute intervals for 1.25 hours post-exercise after each of the runs. At 3:30 pm, if MR had not returned to baseline levels, 30 minute measurements resumed until two consecutive VO_2 measurements were within one standard deviation of resting values for the same time of day.

Treatment 5: Thermic effect of three 15 minute exercise periods and their EPOC with a standard meal between period 1 and 2 (EPOC 3x15 & TEM)

The procedures outlined for the control day were followed until 8:00 am. At 8:00 am, the subject started a 15 minute treadmill run at an intensity eliciting approximately 70% of VO_{2max}.. Metabolic calculations of VO_2, TV, VE, RQ, RR, METs, as well as HR were taken for 5 minutes at the beginning of the run (8:00 am) and for the last five minutes of the run (8:10 am). Immediately upon completion of the exercise at 8:15 am, post-exercise measurements were started; the subject recovered while seated on a chair that was placed on the treadmill belt. The same metabolic measurements were taken for five minutes in 15 minute intervals for 1.25 hours post-exercise. At 9:50 am the subject consumed a liquid meal [Ensure Plus, Ross Laboratories; 53.3% CHO, 32% fat, and 14.7% protein $\bar{X}$=460 kcal (56kcal)] with a caloric content of 10 kilocalories per kilogram of

lean body mass. Subjects had 10 minutes to ingest the drink. Starting at 10:00 am, five minute VO_2 and HR measurements were taken in 15 minute intervals for one hour postprandially. A second 15 minute run was performed at 11:00 am and a third one at 2:00 pm. Metabolic measurements were taken for 5 minutes in 15 minute intervals for 1.25 hours post-exercise after each of the runs. At 3:30 pm, if MR had not returned to baseline levels, 30 minute measurements resumed until two consecutive VO_2 measurements were within one standard deviation of resting values for the same time of day.

Measurements

Standing height: Standing height was measured according to procedures described by Lohman et al. (1988). It was measured to the nearest cm using an anthropometer.

Weight: Body weight was measured in grams with a Toledo digital scale.

Body surface area: Body surface area was calculated from the formula by Du Bois and Du Bois (Carpenter, 1948) using height and weight.

Barometric pressure: Barometric pressure was taken with a Curtin Matheson wall mercury barometer.

Body composition: Body composition was measured by hydrostatic weighing.

1. Residual volume (RV): RV was measured using the oxygen dilution method as described by Wilmore (Appendix G). Each subject performed two trials and their results were averaged.

2. Underwater weighing (UWW): Underwater weight was determined by following standard laboratory procedures (Appendix C).

Body density (D) was calculated as follows:

$D = Wt / [Wt_{air} - (Wt_{water} - Wt_{sinker})/D\ water] - RV$

Percent fat was calculated using Siri's Equation.

$[(4.95/D) - 4.5] \times 100 = \%\ fat$

LBM was calculated using the formula: LBM = Wt - (Wt x % fat)

Maximal oxygen uptake ($VO_{2max.}$): $VO_{2max.}$ was measured through a maximal graded treadmill run to voluntary exhaustion. Subjects started at a speed of either 5.5 or 6.0 mph and 0% grade depending on subject's preference. Speed was kept constant and grade was increased by two percent every three minutes, either until voluntary exhaustion, or a leveling or drop in VO_2 occurred with an increase in workload. 30 second gas samples were analyzed with a Vacumed integrated metabolic system. HRs were monitored with a Vantage Heartrate monitor. Other metabolic measurements included: VCO_2, RQ, VE, TV, and RR. $VO_{2\ max.}$ was defined as the highest per minute value of oxygen consumption reached during the incremental test.

Seventy percent of this maximal workload was estimated mathematically.

Statistical Methodology: Since this was a summary of 5 case studies, only descriptive statistics were used to describe the data. All data is presented graphically in chapter 4. Means and standard deviations for physical and physiological characteristics, as well as VO_2 values for the control and treatment days were calculated to allow for comparisons with other studies, to evaluate the homogeneity of the results, and to observe trends.

CHAPTER 4

RESULTS AND DISCUSSION

The total energy cost of three 15 minute and one 45 minute period of exercise, the EPOC, and a standard liquid meal are presented and discussed for each of the five subjects. Although this is a presentation of five case studies, the means and standard deviations of the five subjects for each treatment are presented to allow for comparisons with other studies, to evaluate the homogeneity of the results, and to show trends. Raw data for oxygen uptakes is presented in Appendix H. Graphs for treatments 2-5 (Graphs 7-29) do not display plotpoints for oxygen uptake during exercise. The scale of the y-axis was adjusted to best show post-exercise changes in VO_2. Heart rate, RQ, RR, TV, and VE values were observed during the study, but are not reported in this paper.

Control Day: Resting Metabolic Rate

The results of this day are presented in more detail in an unpublished research paper (Beithon, et al., 1991). Mean resting metabolic rate for 9.5 hours (8:00 am - 5:00 pm) was .232 l/min (.012) or 3.89 $ml \cdot kg^{-1} \cdot min^{-1}$ (.20) (see Appendix H for individual values). Standard deviations ranged from .015 l/min to .024 l/min or 4.3-7.0 kcal/h.

Treatment 1: Thermic Effect of a Standard Liquid Meal (TEM)

After estimating RMR on the control day, treatment 1 was designed to single out the thermic effect of a liquid meal with a caloric content adjusted to LBM. The thermic effect of a standard liquid meal containing 10 kcal·kg^{-1} of FFM was calculated as the total VO_2 for the measurement period minus the resting oxygen uptake as predetermined by the RMR control day (Table 2).

Table 2

Thermic Effect of a Standard Liquid Meal - VO_2 Calculations

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
Total VO2 (l)	113.850	69.780	82.500	92.835	84.570	99.990
Hours	6.500	5.000	5.500	6.000	6.000	6.500
RMR for x hours	99.678	65.590	76.230	83.442	80.586	90.539
Total - RMR = TEM	14.172	4.190	6.270	9.393	3.984	7.602
					Mean TEM=	7.602
					SD=	4.268

Mean caloric content of the meal was 459.6 kcal. Mean TEM was 7.6 l of oxygen consumed or 36.7 kcal for a mixed diet RQ of .82. The thermic effect of the meal represented 7.97 percent of the ingested calories. This mean value is in agreement with results by Ravussin, et al. (1986) who reported TEF (mixed diet) to account for approximately seven percent of the ingested calories. Schwartz et al. (1985) found the thermic response to a fat or carbohydrate meal to account for 8-13% of the total calories ingested.

A great variability of TEM between subjects was observed. Subjects 2 and 5 both showed a very low response to the caloric

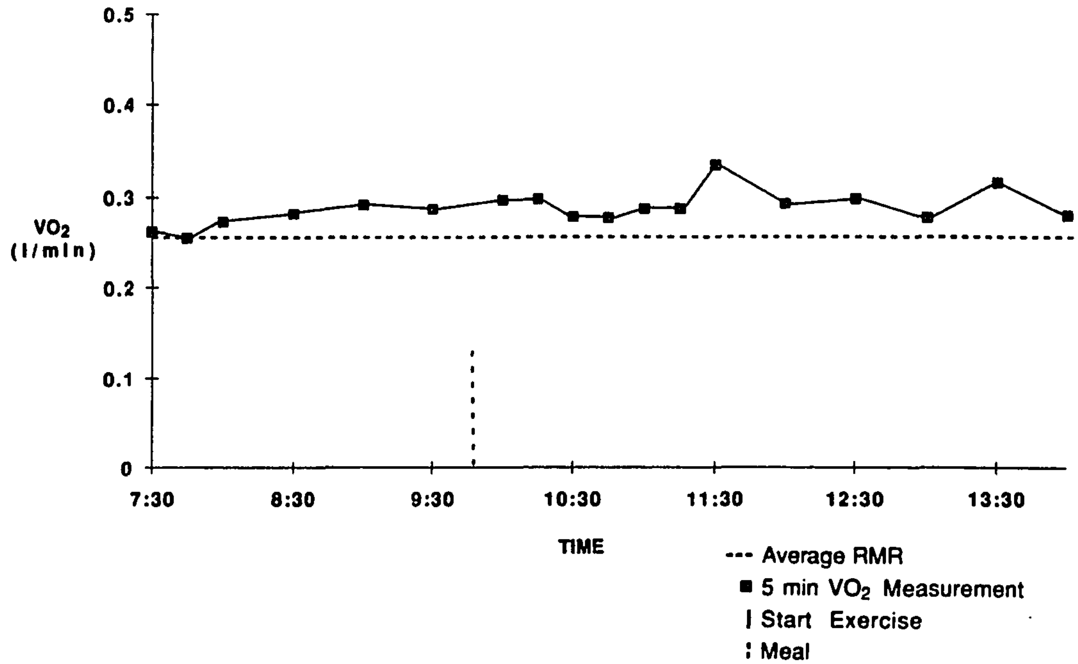
challenge of the meal; 20.2 and 19.2 kcal respectively (4.6/4.2% of ingested calories). In contrast, subject 1 exhibited a large response to the meal (68.4 kcal/12.3% of ingested calories). This difference can not be explained entirely by the bigger absolute caloric content of the meal for subject 1, due to her higher FFM. Some of the variability between subjects may be explained by poor reliability of TEM measurements. A reliability study of TEM measurements has not been performed at our laboratory. A large intra-subject variability of TEM has been observed by other laboratories (Ravussin, et al., 1986). Ravussin et al. (1986) reported a CV (coefficient of variation) of 43% (1-68%) for the determination of the thermic effect of food over a 24 hour period in a human respiratory chamber. The direct calorimetry method used by Ravussin et al. has to be considered as being superior to the open circuit spirometry method used in our study. Thus measurement error, especially in Ravussin's study, does not seem to be a major reason for the intra-subject variability of TEM measurements.

The peak VO_2 response to the meal occured at different times following the meal. Subjects 2 & 3 showed a peak response within the first half hour following the meal (Graphs 2 & 3), whereas subjects 1, 4, and 5 showed their peak response 1.0 - 1.5 hours postprandially (Graphs 1, 4, 5). Individual differences and the above mentioned poor reliability of TEM measurements seem to best explain these differences.

Subject 2 displayed a very short elevation of VO_2 in response to the meal (<60 min - Graph 2). VO_2 for subject 1 was elevated for more than three hours postprandially (Graph 1).

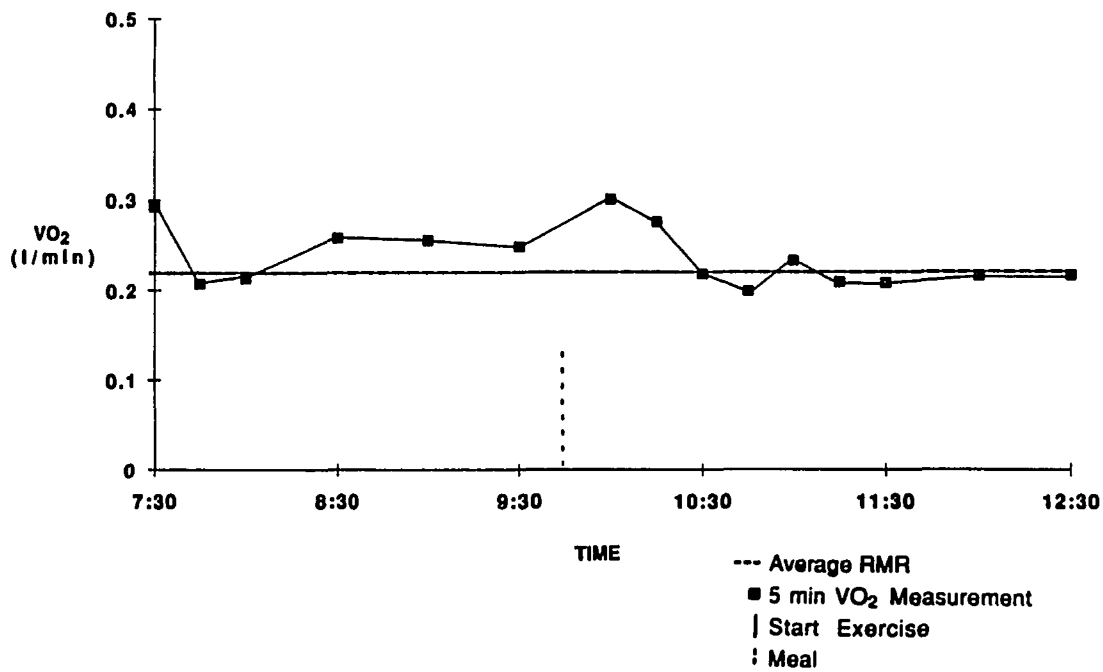
Graph1

Thermic Effect of a Standard Liquid Meal (Subject 1)



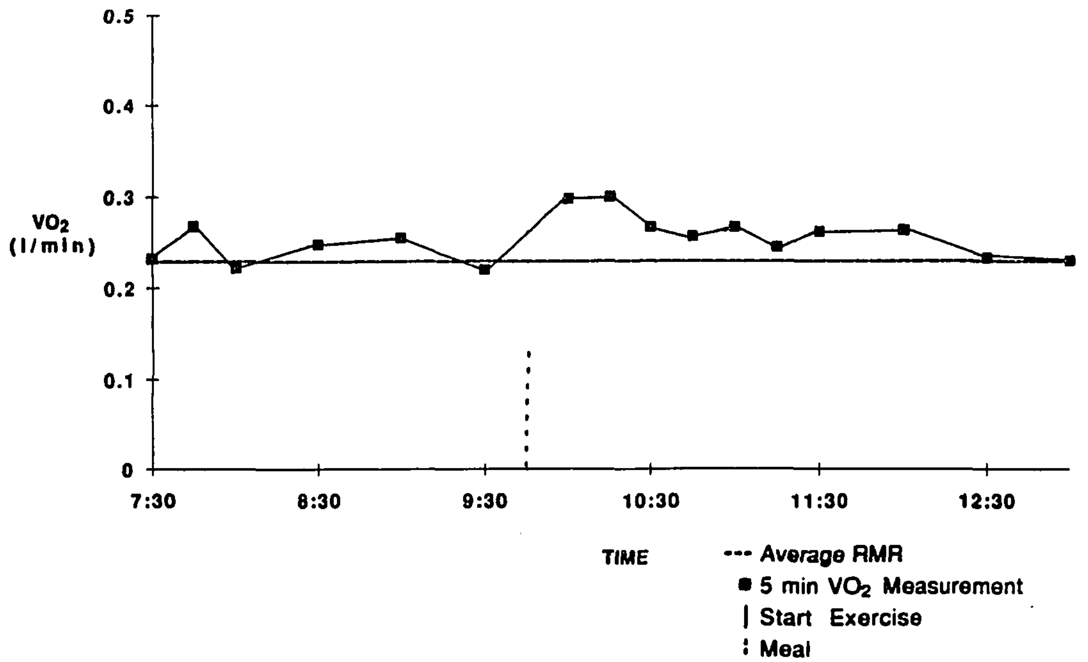
Graph 2

Thermic Effect of a Standard Liquid Meal (Subject 2)



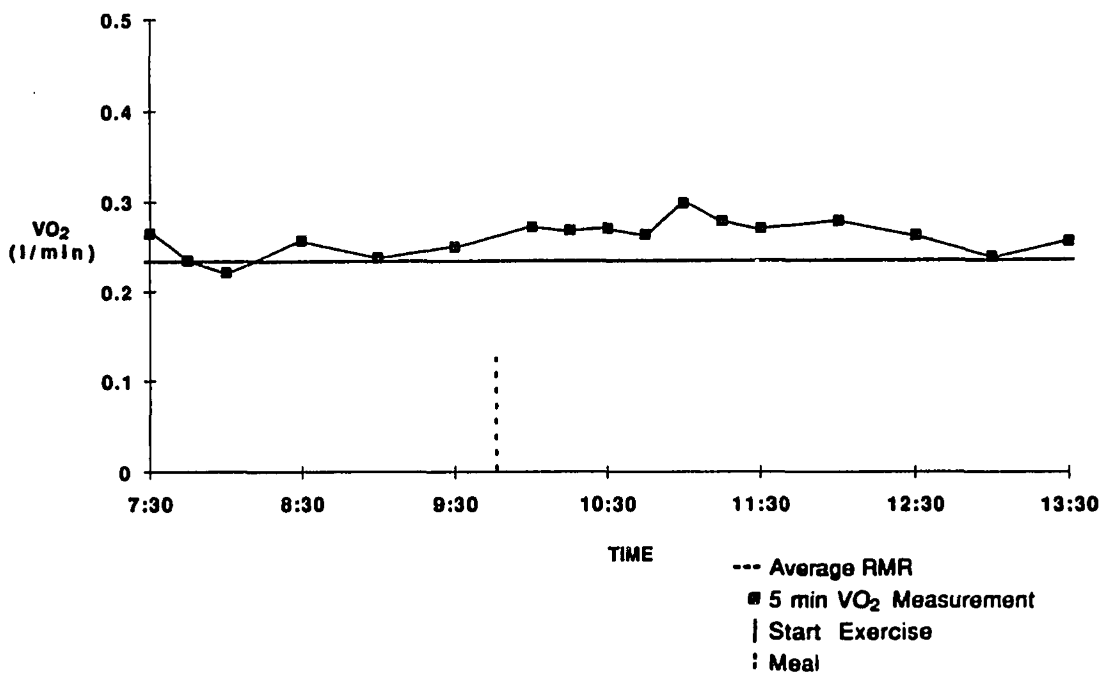
Graph3

Thermic Effect of a Standard Liquid Meal (Subject 3)



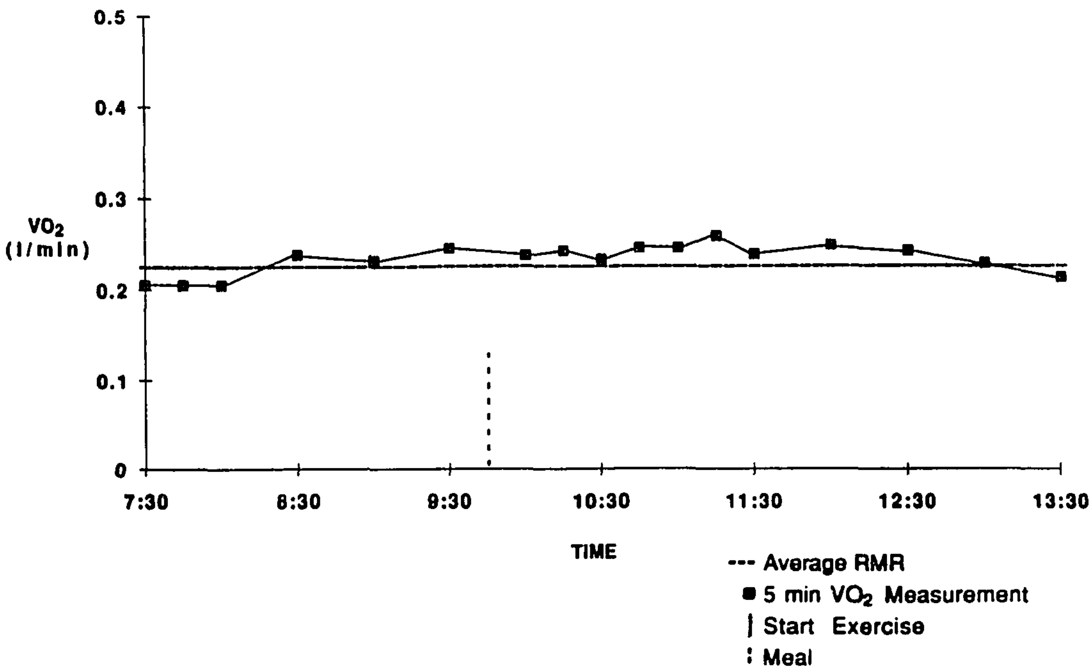
Graph 4

Thermic Effect of a Standard Liquid Meal (Subject 4)



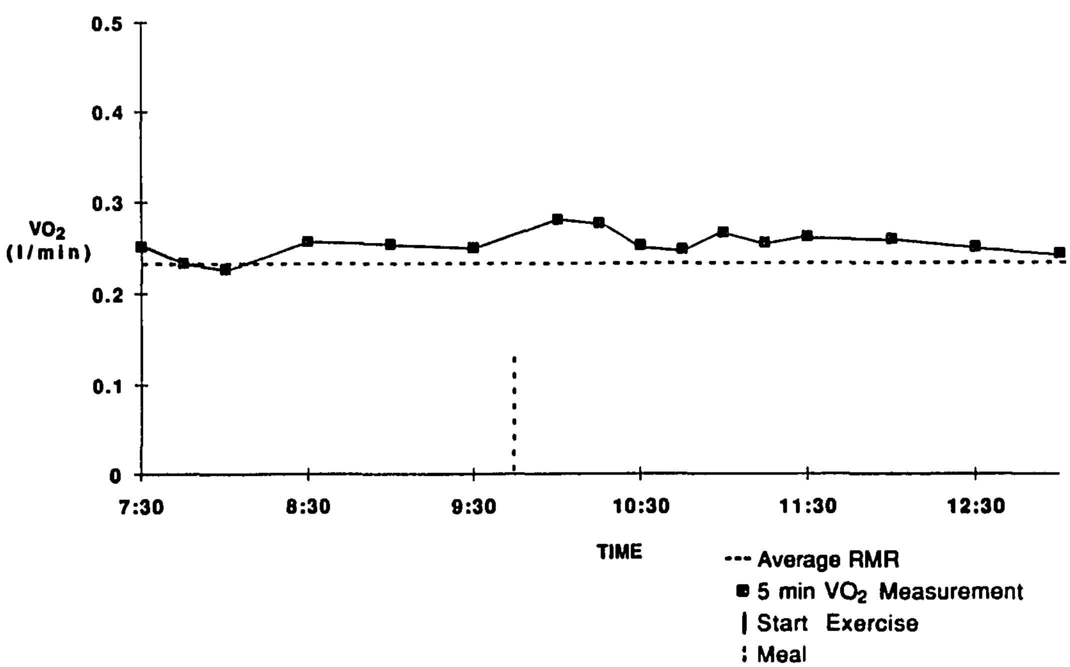
Graph 5

Thermic Effect of a Standard Liquid Meal (Subject 5)



Graph 6

Thermic Effect of a Standard Liquid Meal (Mean-5 Subjects)



Treatment 2: Thermic Effect of a 45 Minute Exercise Period and Its EPOC

In treatment 2, the excess post-exercise oxygen consumption was determined after a single 45 minute run. Mean exercise intensity during the 45 minute run was 71.9% of VO_{2max}.. The excess post-exercise oxygen consumption (EPOC 45) was calculated as follows: total oxygen uptake for the measurement period minus the resting oxygen uptake; the immediate metabolic cost of the 45 minute exercise period was then subtracted and 45 minutes of mean resting oxygen consumption re-added (Table 3). The mean immediate metabolic cost of the 45 min running period was 480 kcal (91.3).

Table 3

Thermic Effect of a 45 min Exercise Period and Its EPOC - VO_2 Calculations

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
Total VO2 (l)	166.715	136.130	132.325	154.685	122.175	142.425
Hours	3.500	3.500	3.500	3.500	3.500	3.500
RMR for x hours	53.673	45.913	48.510	48.675	47.009	48.752
Total - RMR=	113.042	90.217	83.815	106.010	75.166	93.673
minus exercise VO2 (TEE 45)	119.250	94.950	85.950	104.325	81.705	97.230
plus 45 min RMR	11.501	9.839	10.395	10.430	10.073	10.447
equals EPOC=	5.294	5.106	8.260	12.115	3.534	6.890
					Mean=	6.890
					SD=	3.397

Mean EPOC for all subjects was 6.9 l (3.4) or 33 kcal (16.4). This EPOC (33 kcal) represented an additional 6.9% of the calories expended during exercise. These results are in agreement with Bahr's results (Bahr, et al., 1987). Bahr et al. found EPOC to be 6.8% (1.7) of exercise VO_2 after 40 minutes of cycling at 70% of VO_{2max}..

Subject 4 had a larger than average absolute EPOC (12.1 l). This finding was confirmed when EPOC was expressed as a percentage of exercise VO_2 (11.6%). Subjects 1 & 5 showed an EPOC of only 4.4 and 4.3% respectively of exercise VO_2. The high EPOC measurement for subject 4 can possibly be explained by a "feeling of tiredness", reported by the subject during and after the run on this particular treatment day. VO_2 values for all subjects had returned to within one SD of resting values by 2.25 hours post-exercise (Graph 7-12).

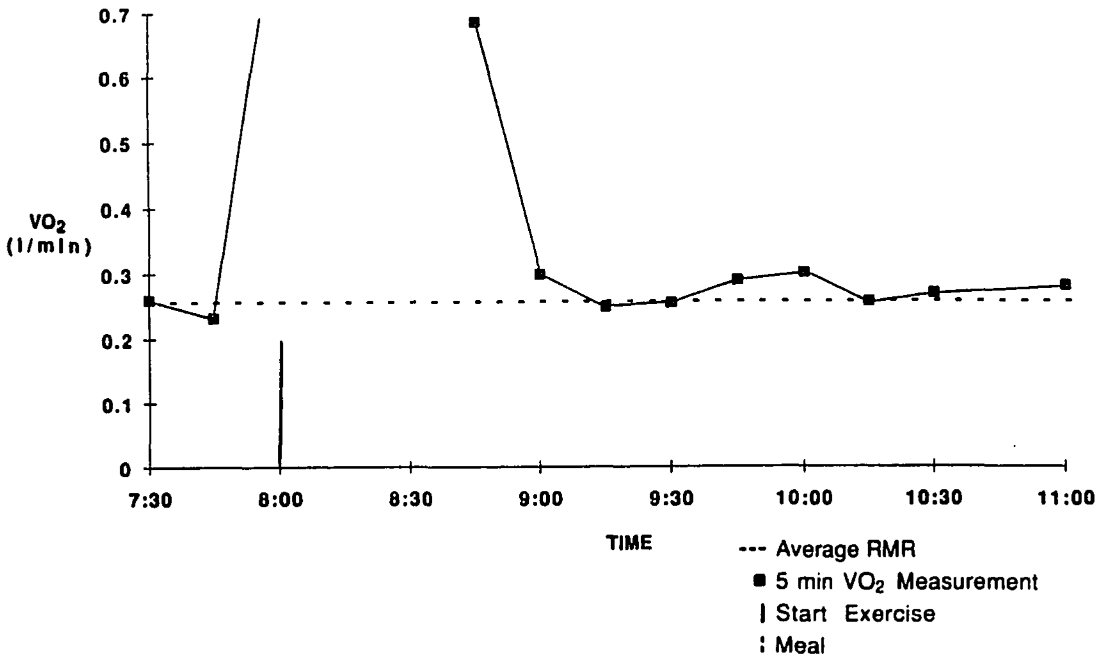
It is extremely difficult to determine if an EPOC of 30 kcal after a 45 minute exercise session is of practical significance or not. The completion of the 45 minutes of running at the prescribed intensity required a great effort from each of the subjects to complete. It is not very likely that the average person is inclined to participate in exercise of similar duration and intensity on a regular basis.

Treatment 3: Thermic Effect of a 45 Minute Exercise Period and Its EPOC Preceding a Standard Meal (EPOC 45 + TEM)

Treatment 3 was a combination of treatments 1 and 2. The exercise, as well as the meal were kept at the same time as during treatments 1 & 2. Exercise intensity (71.9%) as well as meal size ($\bar{X}$ = 460 kcal) was equivalent to treatment 2. The excess post-exercise oxygen consumption in combination with the thermic effect of the meal was calculated as follows: Total VO_2 for measurement period minus resting oxygen uptake, minus exercise VO_2, plus 45 minutes of average resting VO_2 (Table 4). No distinction could be

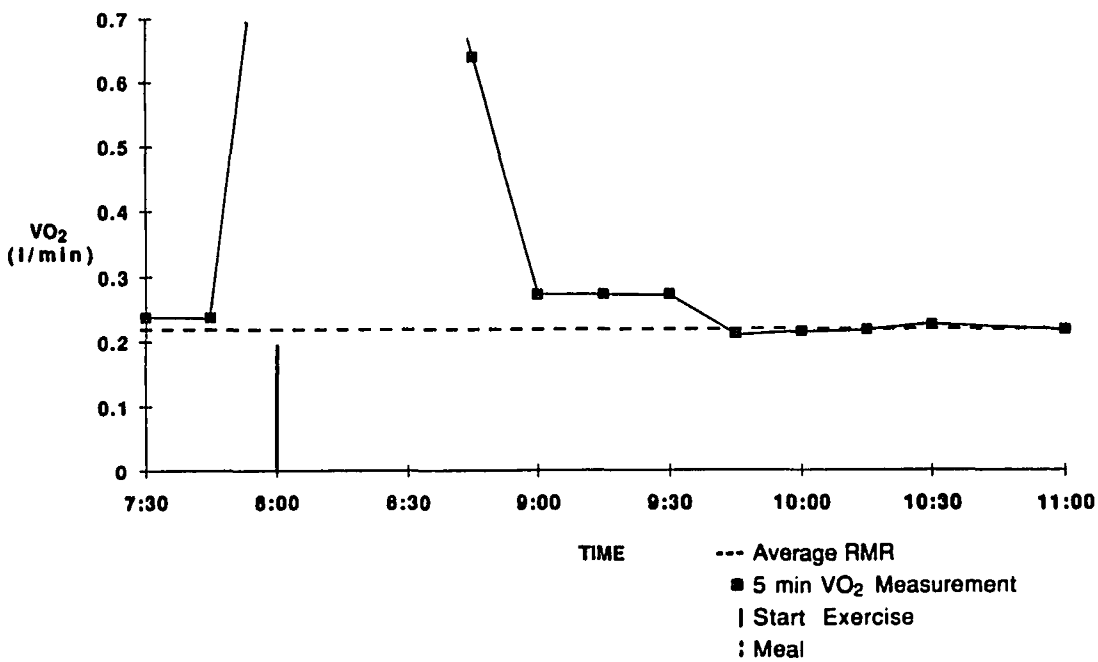
Graph 7

Thermic Effect of a 45 min Exercise Period and Its EPOC (Subject 1)



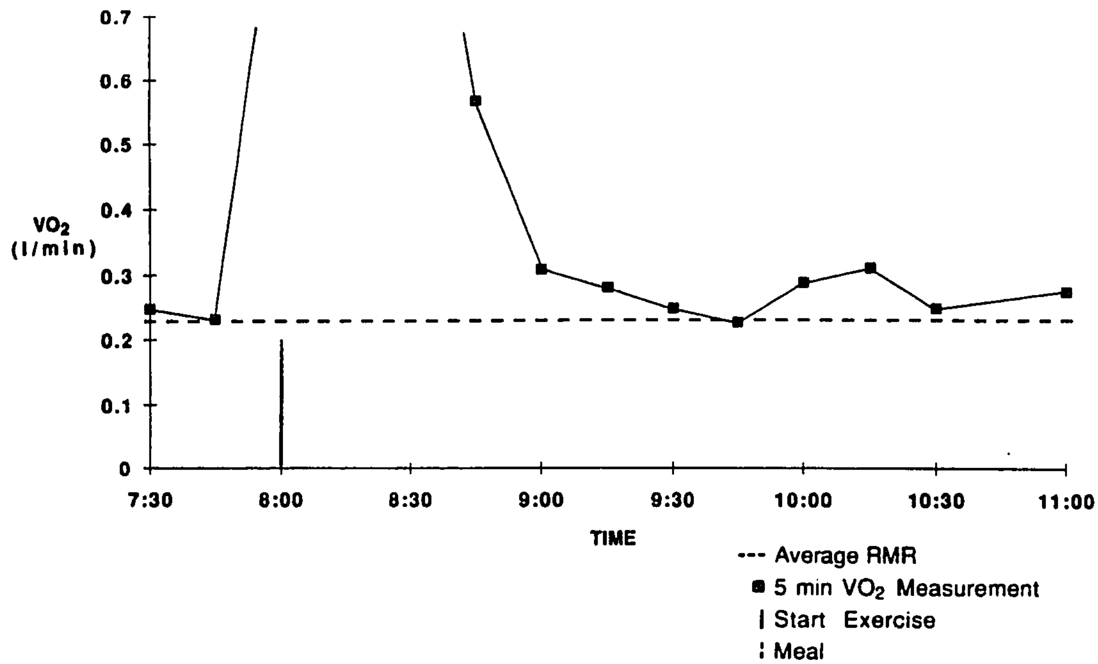
Graph 8

Thermic Effect of a 45 min Exercise Period and Its EPOC (Subject 2)



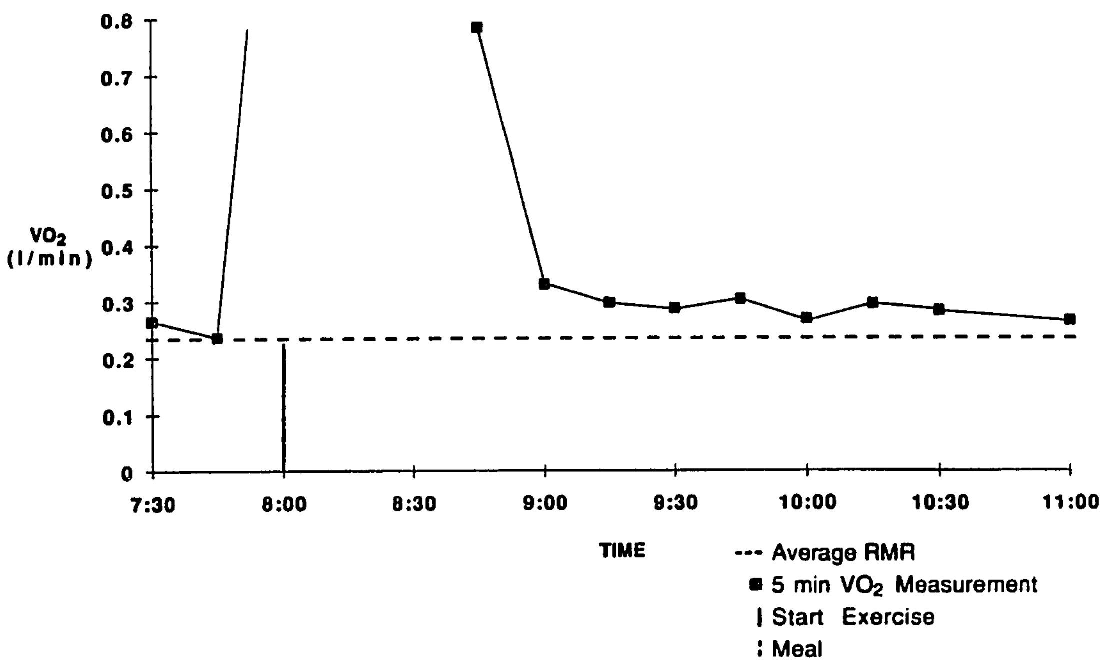
Graph 9

Thermic Effect of a 45 min Exercise Period and Its EPOC (Subject 3)



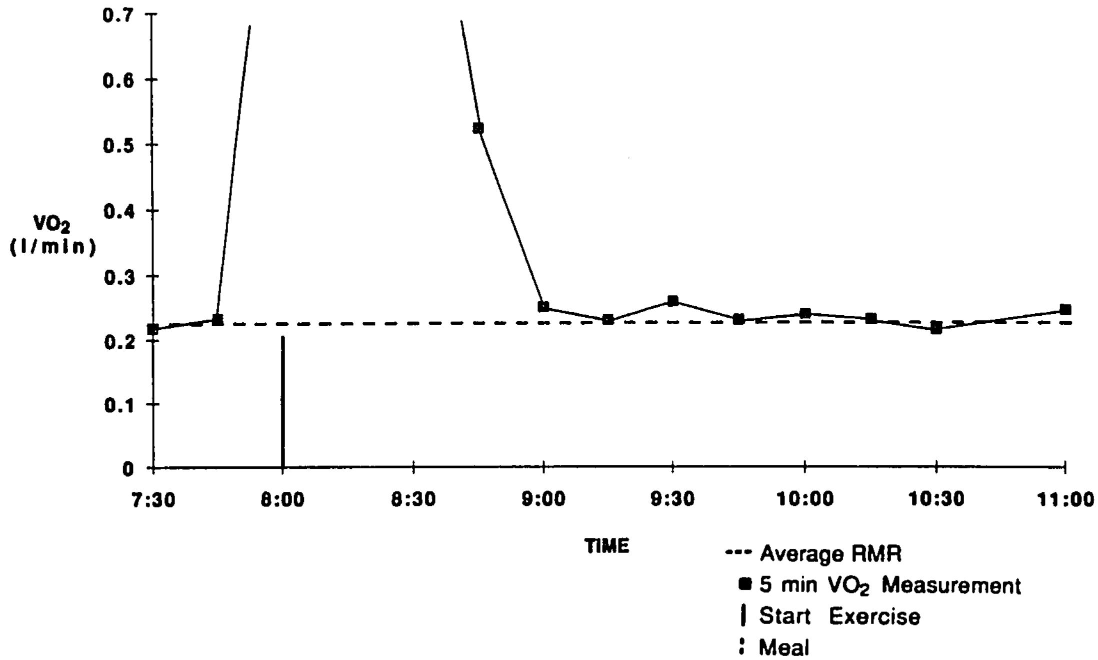
Graph 10

Thermic Effect of a 45 min Exercise Period and Its EPOC (Subject 4)



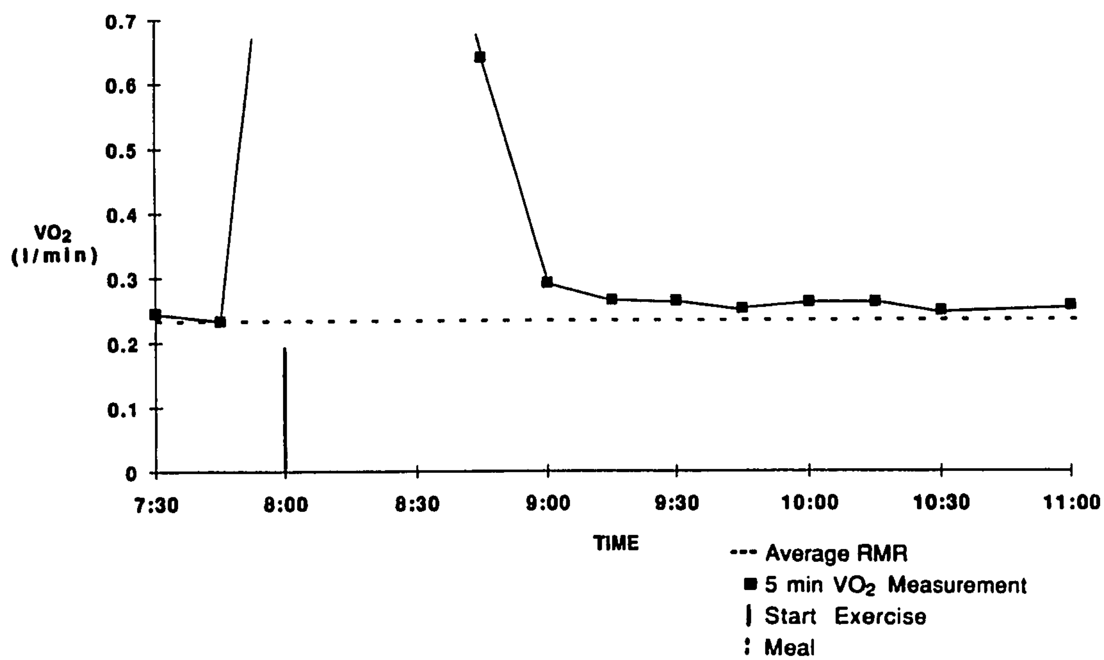
Graph 11

Thermic Effect of a 45 min Exercise Period and Its EPOC (Subject 5)



Graph 12

Thermic Effect of a 45 min Exercise Period and Its EPOC (Mean-5 Subjects)



made between EPOC and TEM, since the end of EPOC and the beginning of TEM overlap (Graph 11). The combined mean EPOC and TEM was 12.8 l (4.7) or 61.8 kcal (22.7).

Table 4

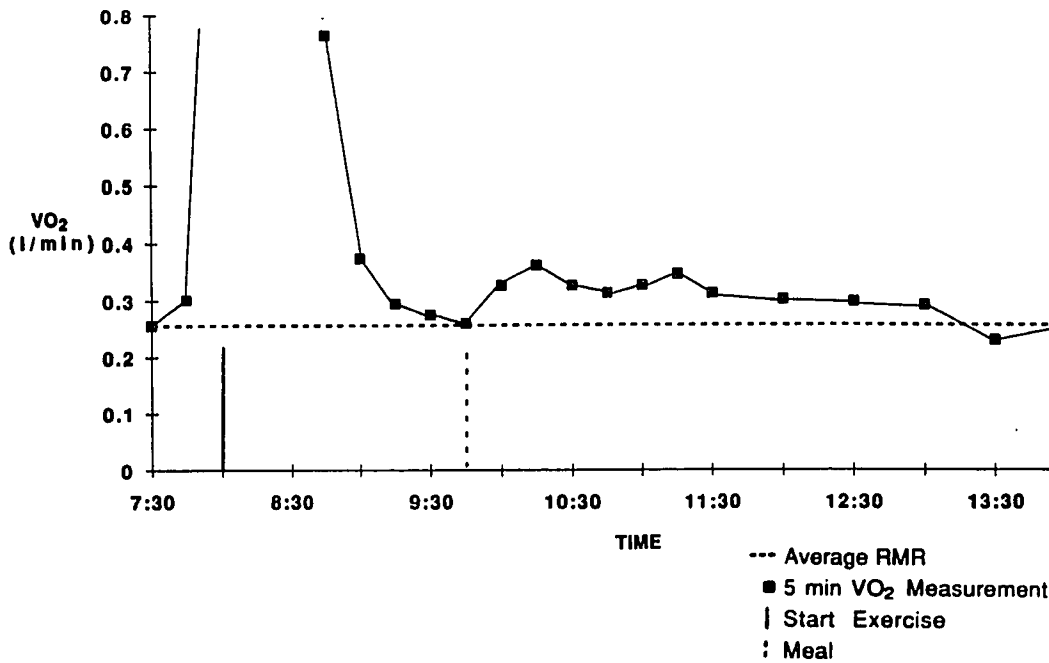
Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal - VO_2 Calculations

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
Total VO2 (l)	236.590	177.020	172.215	169.225	157.020	192.695
Hours	6.500	5.500	6.000	5.000	6.000	6.500
RMR for x hours	99.678	72.149	83.160	69.535	80.586	90.539
Total - RMR=	136.912	104.871	89.055	99.690	76.434	102.156
minus exercise VO2 (TEE45)	130.230	98.850	85.380	101.700	79.200	99.075
plus 45 min RMR	11.501	9.839	10.395	10.430	10.073	10.447
equals TEM + EPOC	18.183	15.860	14.070	8.420	7.307	12.768
					Mean=	12.768
					SD=	4.725

Subject 1 showed the highest response to the exercise and the meal (18.2 l) and subject 5 displayed the lowest response (7.3 l). Considering the higher overall resting and exercise VO_2 of subject 1, these results would have been expected. VO_2 values for all subjects had returned to resting levels by 2:00 pm (Appendix H). VO_2 values returned close to resting levels after cessation of exercise, immediately preprandial (Graphs 13-18). As expected, 1 hour post-exercise recovery was almost identical to treatment 2 (Graphs 12 & 18). The TEM for subject 2 was considerably larger (higher peak and longer duration) when coupled with the preprandial exercise in this treatment (Graphs 2 & 13). Peak VO_2 was delayed (1.25 h postprandial) in subject 5 when compared to other subjects, whose peak response occured immediately after ingestion of the meal

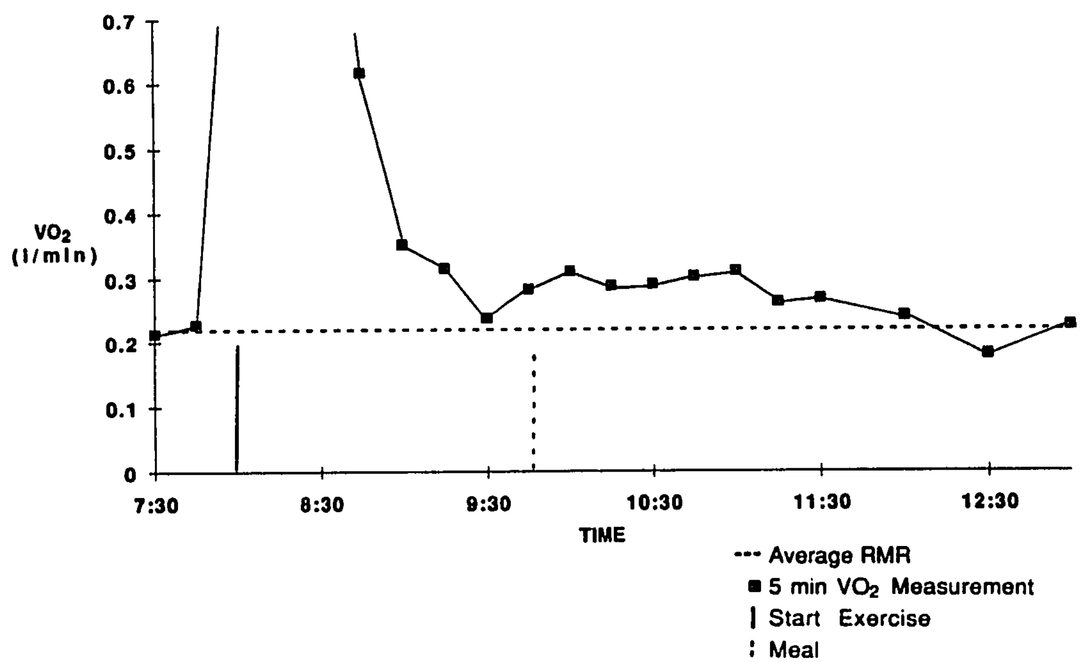
Graph 13

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal (Subject 1)



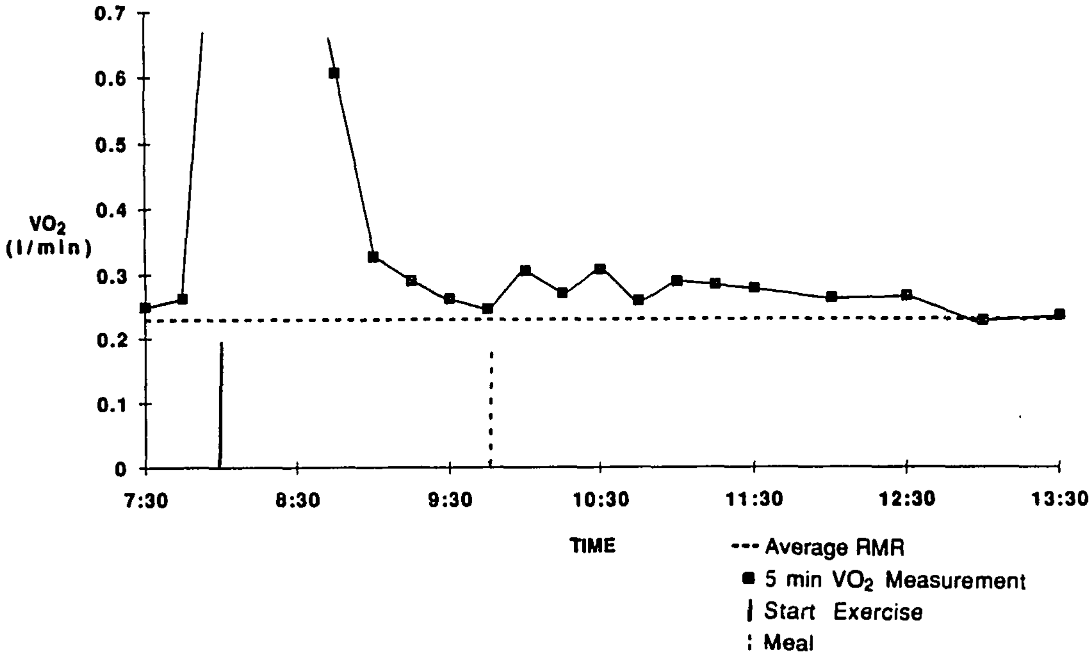
Graph 14

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal (Subject 2)



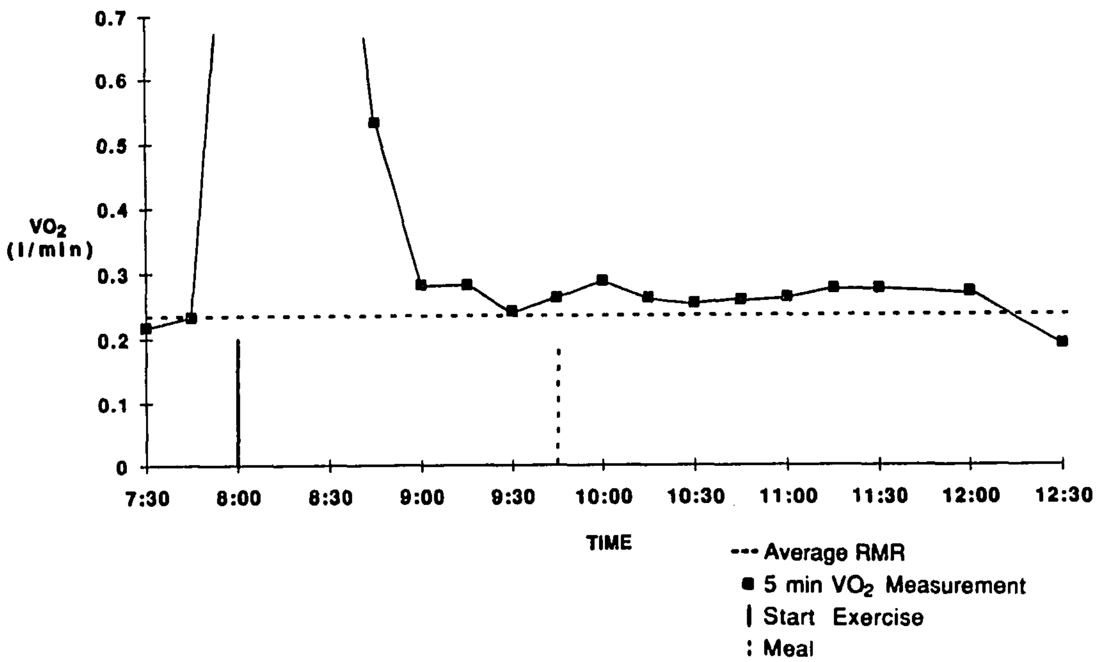
Graph15

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal (Subject 3)



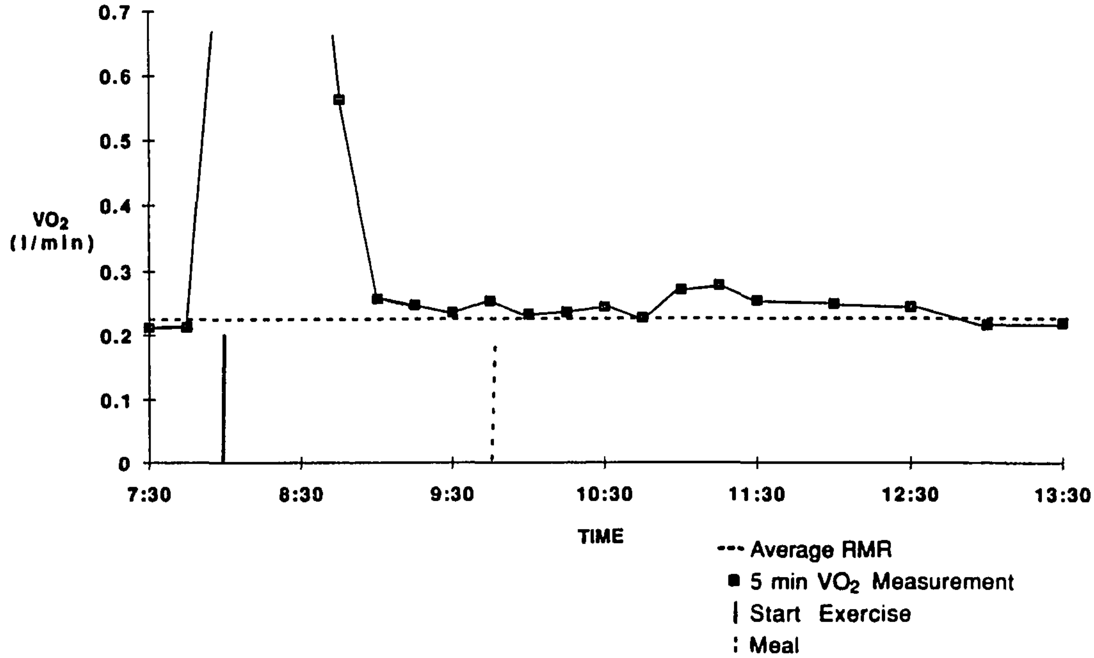
Graph 16

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal (Subject 4)



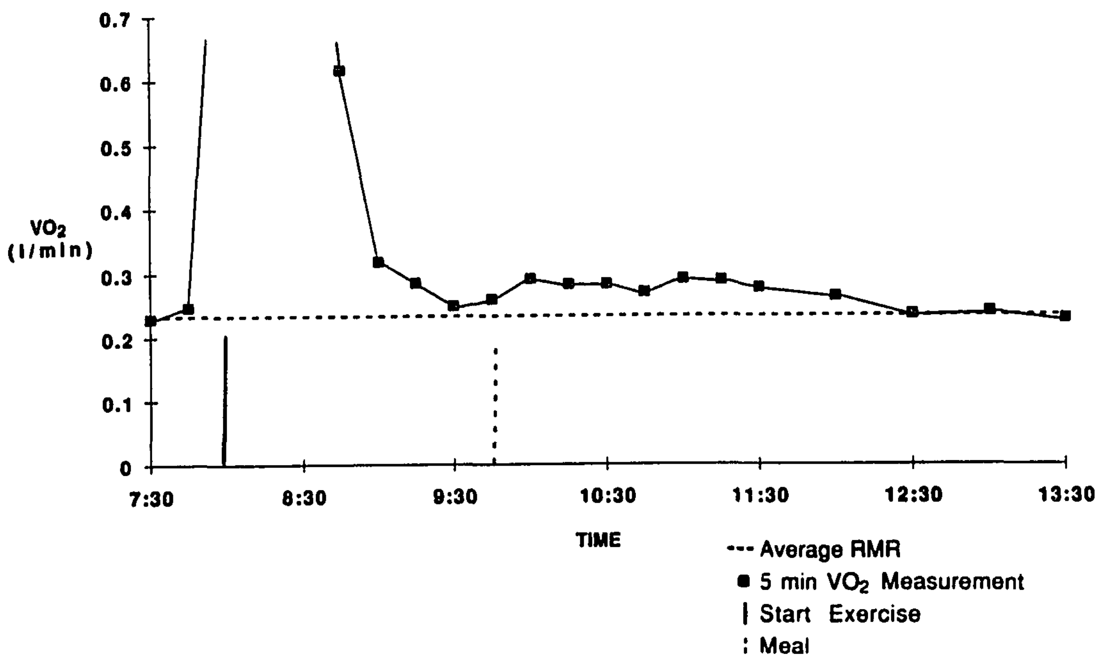
Graph 17

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal (Subject 5)



Graph 18

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal (Mean-5 Subjects)



(Graph 17). This early peak probably occured because of the residual effect of the exercise that still persisted at the time of the consumption of the meal.

Treatment 4: Thermic Effect of Three 15 Minute Exercise Periods and Their EPOC

Mean exercise intensity for all three running periods was identical to exercise intensity during the 45 minute run. The combined EPOC after three exercise periods was calculated as follows: Total VO_2 for measurement period, minus average resting VO_2, minus exercise VO_2 (3x15min), plus 45 minutes of average resting oxygen uptake (Table 5).

Table 5

Thermic Effect of Three 15 min Exercise Periods and Their EPOC - VO_2 Calculations

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
Total VO2 (l)	266.860	193.495	197.290	211.935	193.037	223.855
Hours	8.500	7.500	8.000	7.500	7.500	8.500
RMR for x hours	130.348	98.385	110.880	104.303	100.733	118.397
Total - RMR=	136.512	95.110	86.410	107.632	92.304	105.458
minus exercise VO2 (TEE3x15)	130.770	92.850	81.000	106.546	84.070	99.047
plus 45 min RMR	11.501	9.839	10.395	10.430	10.073	10.447
equals EPOC 3x15=	17.234	12.099	15.805	11.516	18.307	14.992
			Mean EPOC (3x15)=			14.992
					SD=	3.047

Mean EPOC (3x15) was 15.0 l (3.0) or 72 kcal (14.5). This represented an EPOC, that on the average was 8.1 liters greater than

in treatment 2 (EPOC 45). The results also showed little variation when compared with the other treatments.

Subject 5 had the highest EPOC in response to the three 15 minute running periods (18.3 l). This finding was surprising, considering her low thermic response to the two 45 minute exercise treatments (EPOC45 = 3.5 l & EPOC45TEM = 7.3 l). As for subject 4 in treatment 2, extreme fatigue possibly caused oxygen uptake to stay elevated during subject 5's recovery. VO_2 values returned to resting levels between exercise periods for all subjects except subject 5 (Graph 23). As expected, post-exercise VO_2 elevation persisted for less than 1 hour after all three periods (Subjects 1-4; Graphs 19-22). The short duration of exercise is presumed to be the determining factor for the brief elevation of RMR.

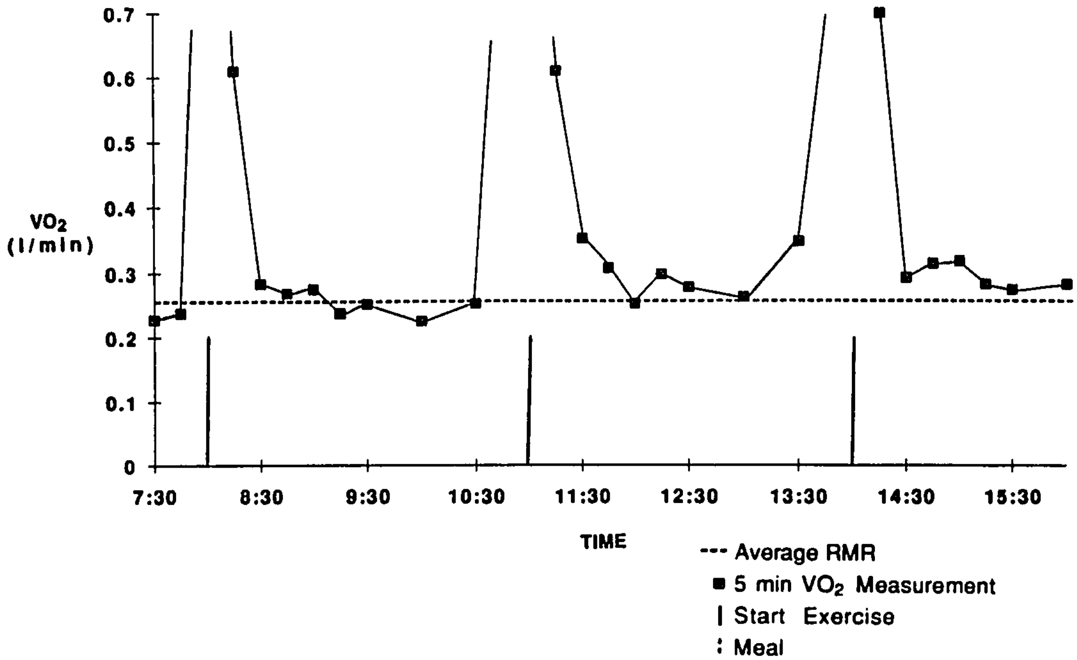
The overall EPOC, however, in conjunction with three 15 minute periods, was more than twice the magnitude of the EPOC after 45 minutes of running. There are no similar studies which would allow for a comparison of the results of this treatment.

<u>Treatment 5: Thermic Effect of Three 15 Minute Exercise Periods and Their EPOC with a Standard Meal between Periods One and Two</u>

Mean exercise intensity was again the same as in treatments 2-4. Subject 5 did not complete treatment 5 due to an injury. The combined EPOC (after three 15 min running periods) and the thermic effect of a standard meal were calculated as follows: total VO_2 for the measurement period, minus average resting VO_2, minus exercise

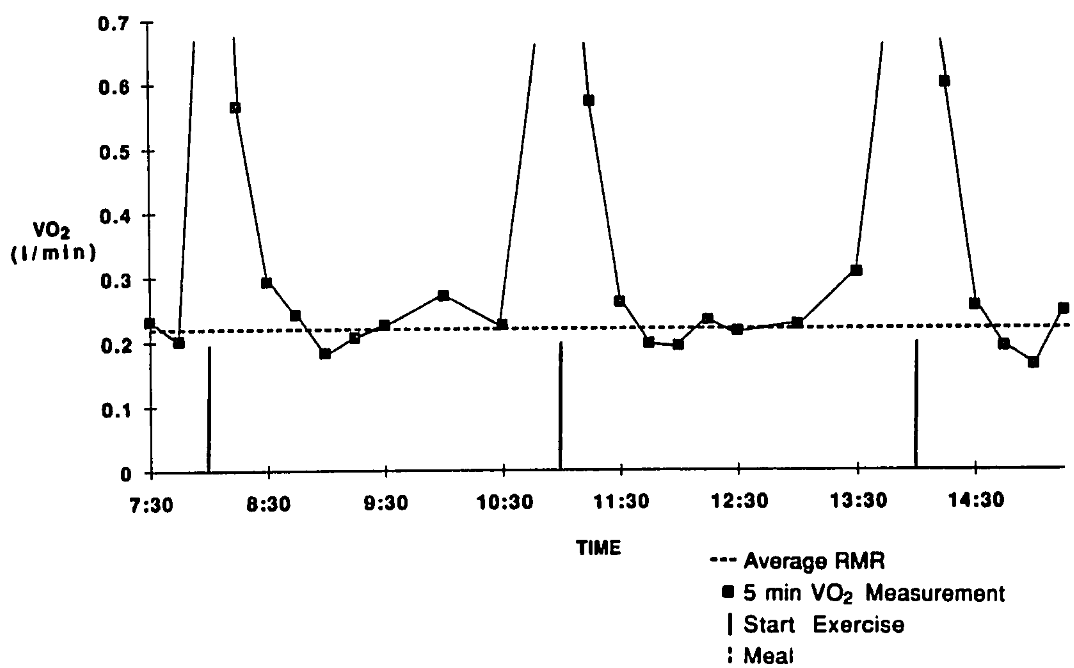
Graph 19

Thermic Effect of Three 15 min Exercise Periods and Their EPOC (Subject 1)



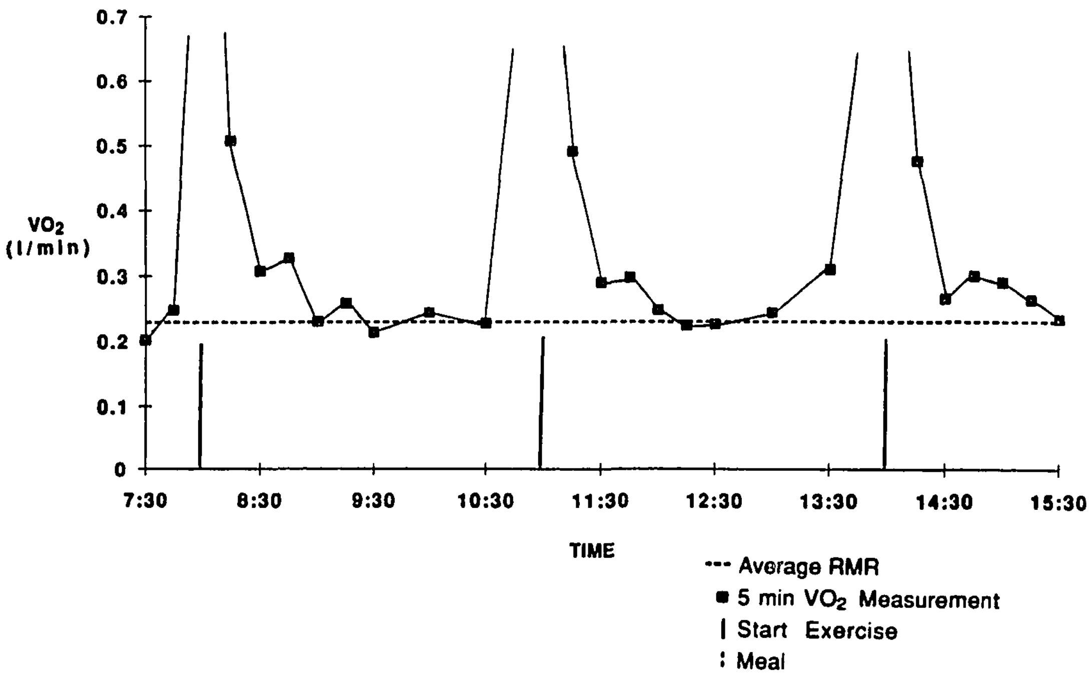
Graph 20

Thermic Effect of Three 15 min Exercise Periods and Their EPOC (Subject 2)



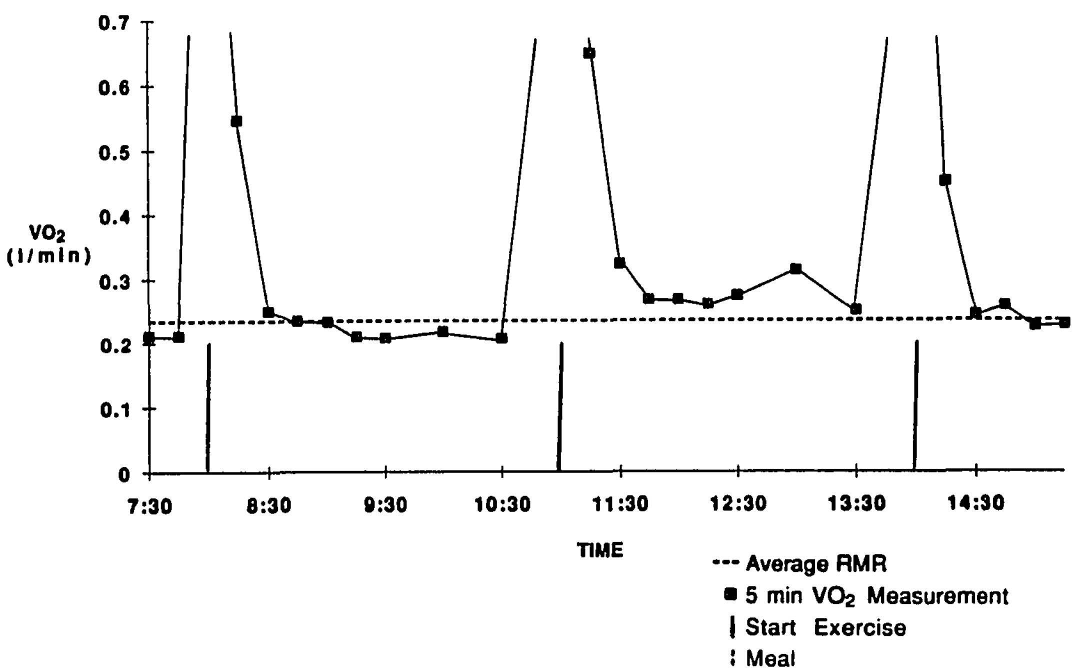
Graph 21

Thermic Effect of Three 15 min Exercise Periods and Their EPOC (Subject 3)



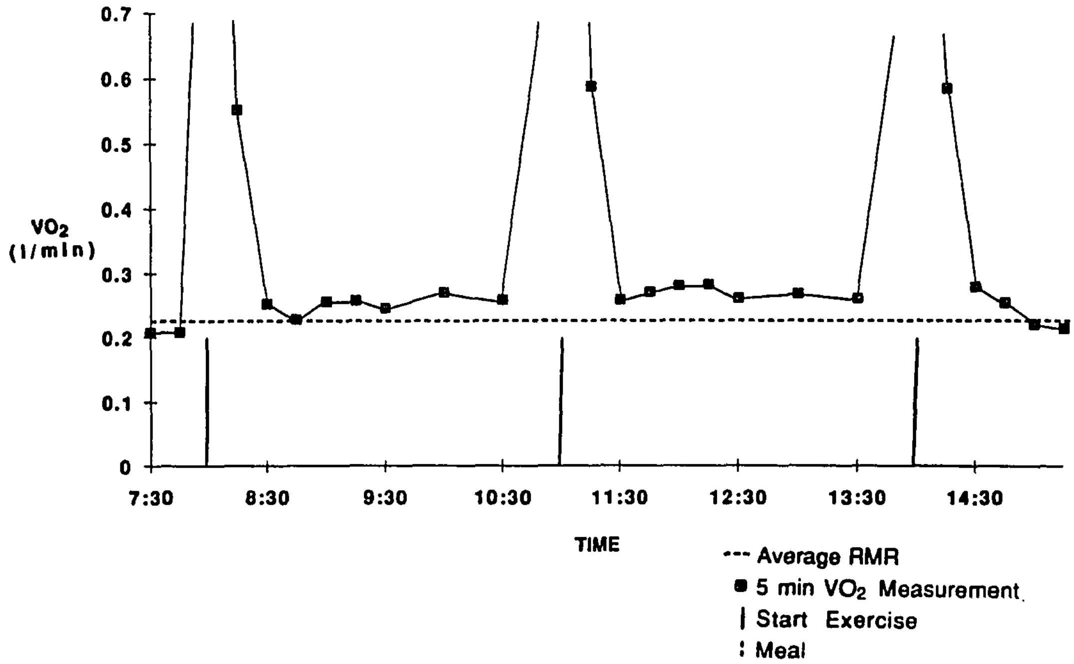
Graph 22

Thermic Effect of Three 15 min Exercise Periods and Their EPOC (Subject 4)



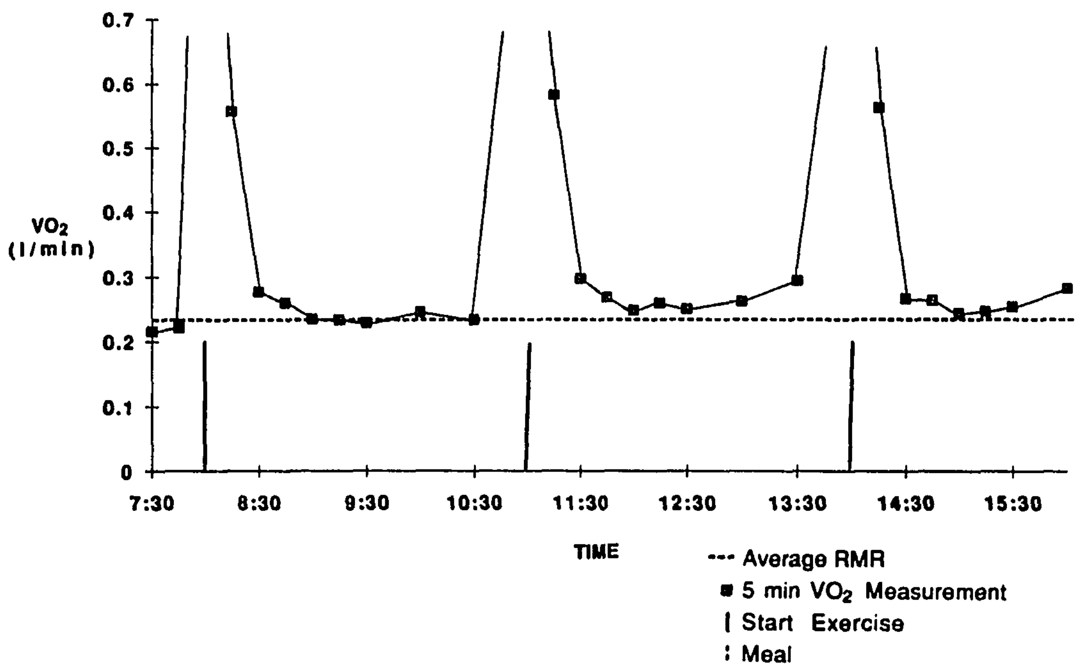
Graph 23

Thermic Effect of Three 15 min Exercise Periods and Their EPOC (Subject 5)



Graph 24

Thermic Effect of Three 15 min Exercise Periods and Their EPOC (Mean-5 Subjects)



VO_2 (3x15min), plus 45 minutes of average resting oxygen uptake (Table 6).

Table 6

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two - VO_2 Calculations

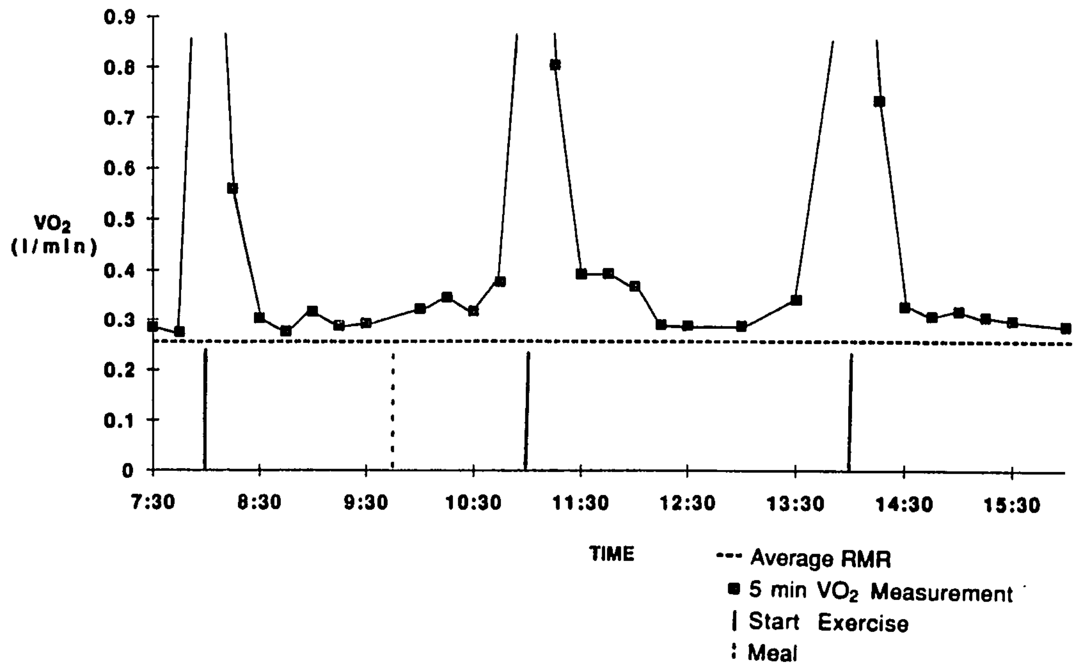
	Subject 1	Subject 2	Subject 3	Subject 4	Average
Total VO2 (l)	289.598	219.050	199.082	208.915	240.508
Hours	8.500	7.500	8.000	7.250	8.500
RMR for x hours	130.348	98.385	110.880	100.826	118.397
Total - RMR=	159.250	120.665	88.202	108.089	122.111
minus exercise VO2 (TEE 3x15)	136.418	102.376	84.188	100.816	105.954
plus 45 min RMR	11.501	9.839	10.395	10.430	10.447
equals TEM + EPOC 3x15	34.333	28.128	14.410	17.703	23.644
				Mean=	23.644
				SD=	9.218

As in treatment 3, no distinction between EPOC and TEM could be made because of the overlapping of TEM and EPOC (Graph 29). The combined mean EPOC & TEM was 23.6 l (9.2) or 114 kcal (44.4). As already observed in treatment 3 (EPOC45 & TEM), subjects 1 and 2 showed very large thermic responses (Subject 1 = 34.3 l; Subject 2 = 28.1 l) in contrast to subjects 3 and 4 (Subject 3 = 14.4 l; Subject 4 = 17.7 l). Especially subject 2, who's TEM, when measured separately on treatment day 1 was small, had an extremely large thermic response to the same meal when in conjunction with either 45 minutes of preprandial exercise or 15 minutes pre- and two 15 minute postprandial exercise periods (Graphs 2, 14, 26).

Even though data was not treated statistically, there appears to be a greater excess post-exercise O_2 consumption associated with three running periods when comparing treatment 5 (EPOC 3x15 &

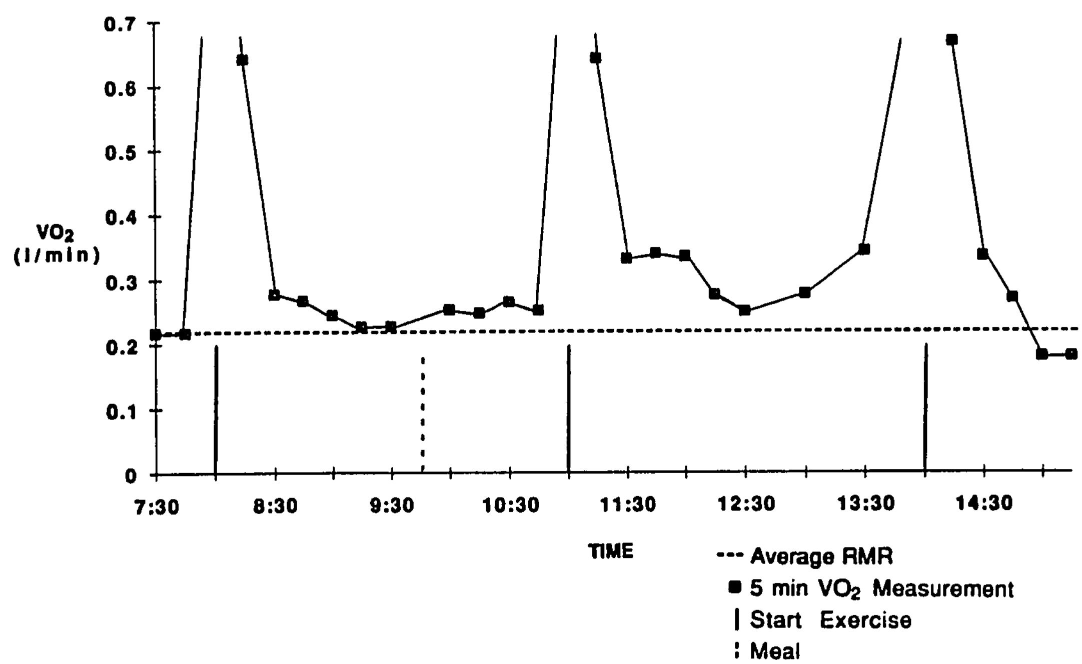
Graph 25

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two (Subject 1)



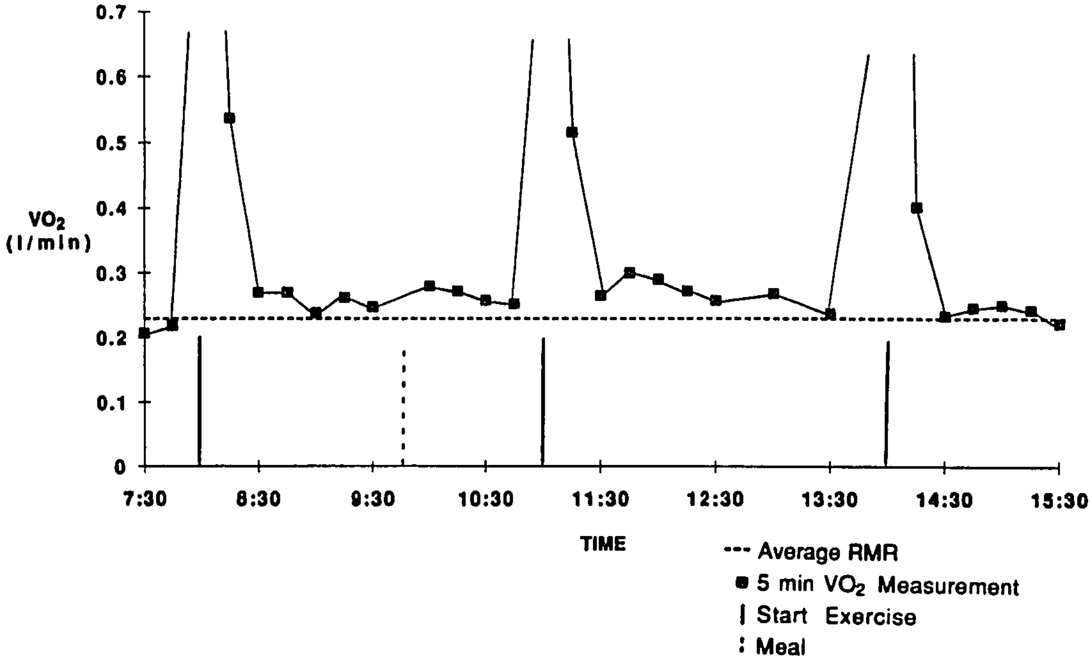
Graph 26

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two (Subject 2)



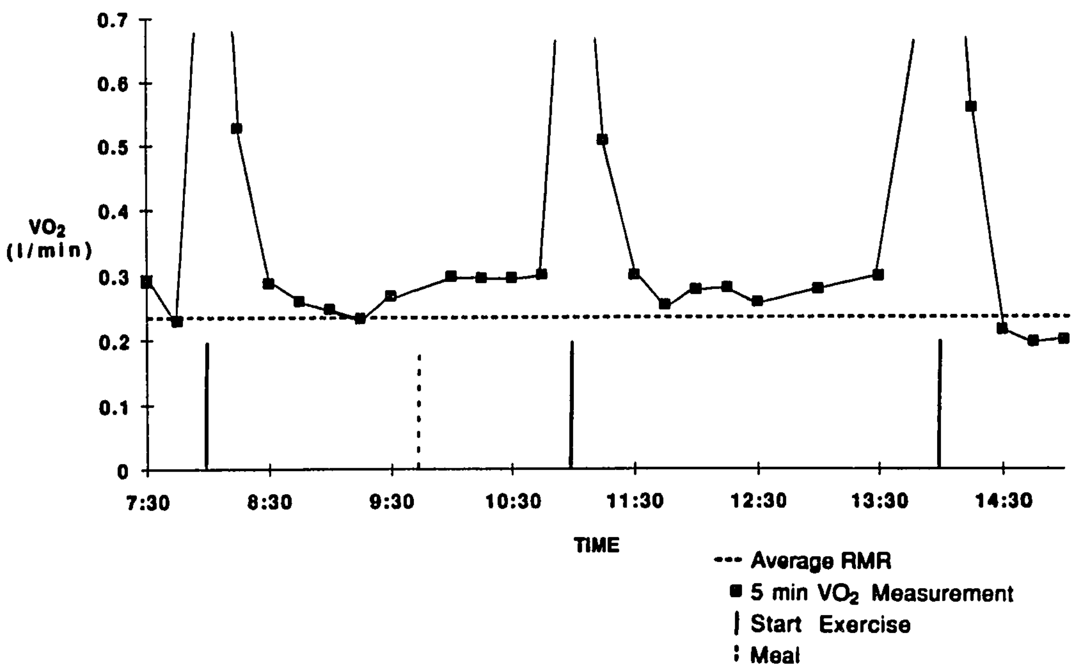
Graph 27

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two (Subject 3)



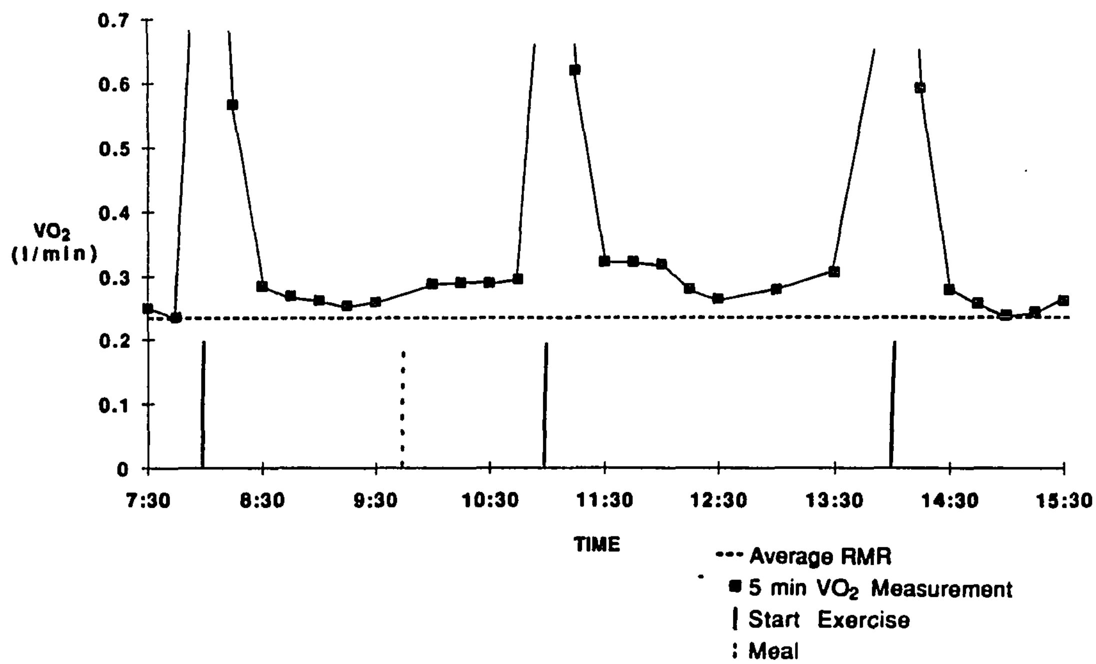
Graph 28

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two (Subject 4)



Graph 29

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two (Mean-4 Subjects)



TEM) to treatment 3 (EPOC 45 & TEM). On average, EPOC 3x15 & TEM was 10.8 l (52.2 kcal) larger than EPOC 45 & TEM, which indicates a possible higher overall caloric expenditure throughout the day in conjunction with multiple exercise periods.

VO_2 did not return to average RMR between running periods one and two (Graph 29). VO_2 declined rapidly in all subjects until the thermic effect of the meal set in (9:50 am). Between exercise periods 2 and 3 (11:00 am - 2:00 pm) VO_2 was elevated more than one standard deviation above average resting values for subjects 1, 2, and 4 (Graph 25, 26, 28; Appendix H). VO_2 for subject 3 was elevated more than one standard deviation above average resting VO_2 until 1:30 pm (Appendix H). The VO_2 measurement at 1:30 pm revealed an oxygen uptake of .237 l/min (Mean RMR = .231 l/min; mean + 1 SD = .235 l). VO_2 quickly returned to control levels after exercise period 3 for subjects 2, 3, and 4 (Appendix H). In subject 1, VO_2 did not return to average RMR at the end of the treatment day, but was within one standard deviation of control levels for the same time of the day (Appendix H; Graph 25).

Summary

This study demonstrated that EPOC persists for less than 2.25 hours after 45 minutes of running at 70% of VO_{2max}.. EPOC was even smaller after 15 minutes of exercise. The combined EPOC after three 15 minute exercise periods, however, was more than twice the amount of energy expended after the single 45 minute period. In

combination with the thermic effect of a meal, this difference was even more pronounced.

CHAPTER 5

SUMMARY

This study had several purposes:

1. To measure the thermic effect of a standard liquid meal.
2. To measure the combined thermic effect of a 45 minute exercise period at 70% of $VO_{2max.}$, the excess post-exercise oxygen consumption (EPOC), and the thermic effect of the standard liquid meal ingested 60 minutes after exercise.
3. To measure the combined thermic effect of three separate 15 minute exercise sessions each at 70% of $VO_{2max.}$ and spread three hours apart; the EPOC for each session, and the thermic effect of the standard liquid meal ingested between exercise sessions one and two.
4. To compare 2. and 3. above.

Five apparently healthy females [Wt. = 59.6 kg (8.0); Age = 26.2 (4.4); % Fat = 22.4 (4.7); $VO_{2max.}$ = 51.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (7.8)] volunteered for this study. The study was treated as five case studies; however, the subjects' data were also averaged for descriptive purposes. Only descriptive statistics and graphs were used to study the data. All five subjects initially were tested 9.5 hours to determine average RMR. This was used as a baseline for the following five treatment days:

1. The thermic effect of a standard liquid meal (TEM) with a caloric content of 10 kcal/kg of LBM [$\bar{X}$ = 460 kcal (56.4)] and a

composition of 53.3% CHO, 32.0% fat, and 14.7% protein.

2. The EPOC after a 45 minute exercise period at 70 % of VO_{2max}..

3. The thermic effect of a 45 minute exercise period and its EPOC preceding a standard meal.

4. The thermic effect of three separate 15 minute exercise periods and their EPOC.

5. The thermic effect of three 15 minute exercise periods and their EPOC, with a standard meal between periods one and two.

Subjects displayed a large variability in response to treatments one and two. The standard deviation of the TEM results, despite the adjustment of the caloric challenge to FFM, was greater than 50% of the mean. VO_2 values did return to resting values for all subjects within 2.25 hours after the 45 minute exercise period. Four out of five subjects had returned to control levels after one hour post-exercise. VO_2 values rapidly returned to average resting VO_2 after each one of the 15 minute exercise periods (Treatment 4). The combined EPOC of all three periods, however, was approximately twice the magnitude of the excess post-exercise O_2 consumption after 45 minutes of running.

When the 45 minute exercise period was coupled with a standard liquid meal (1 hour post-exercise), VO_2 was elevated for up to four hours postprandially. In four of the five subjects, the peak VO_2 response occured immediately after ingestion of the meal, probably due to the residual effect of the exercise. VO_2 values rapidly declined to average resting levels after exercise period one in

treatment five (see above), until the thermic effect of the meal set in. Between the second exercise period, which started one hour postprandial, and the third running period, VO_2 values were elevated more than one standard deviation above average RMR levels. VO_2 quickly returned to resting levels after exercise period three.

On average, the combined EPOC and TEM after the 45 minute exercise period was less than half the magnitude of the combined EPOC of three 15 minute running periods and the thermic effect of a standard liquid meal.

Conclusions

Previous studies have shown oxygen consumption to be increased anywhere from less than 30 minutes to more than 24 hours after exercise of varying intensities, durations, and modes. The main purpose of this study was not to determine the duration or magnitude of EPOC, but rather to investigate the possibility of a higher overall energy expenditure by dividing a 45 minute running period into three 15 minute periods. Since this study was a summary of five case studies, no inferences about the general population can be made. Several trends which could lead to future investigations were observed.

1. An increased oxygen consumption after either 45 min, or 3x15 min of exercise, or a standard liquid meal was observed in all subjects. There was a large variation within and between subjects in the magnitude and duration of this elevation.
2. After 45 minutes of exercise at a mean intensity of 71.9% of

$VO_{2max.}$, oxygen uptake returned to control levels within 2.25 hours in all subjects.

3. When exercise of identical mode, intensity, and overall duration was divided into several (3) shorter exercise periods, spread apart throughout the day, the combined EPOC after three exercise periods was more than twice the magnitude of the EPOC after a single exercise period.

4. The same effect as in 3. was even more pronounced when exercise was followed by a standard liquid meal.

Recommendations

Based on the results of this study, no definitive recommendations for training can be given. As known previously, for exercise to have a sustained effect on RMR (significant EPOC), the exercise has to be intense and of long duration. Multiple exercise periods might have a greater combined EPOC than single exercise periods of the same overall intensity and duration. The impact of this possibly increased EPOC on weight loss is very difficult to evaluate, but should be the subject of future investigations.

The following are recommendations for further research:

1. Instead of a mouthpiece, a hood system should be used in conjunction with the metabolic system. This would alleviate possible increases of RMR due to subject discomfort, caused by continuous breathing through a mouthpiece.

2. The reliability of TEM measurements needs further evaluation.

3. VO_2 measurements should be continuous during short exercise periods (< 20 min), and for the first 60 minutes post-exercise.

4. A larger sample size is needed to allow inferences about the population.

5. The combined thermic effect of three exercise periods and three meals should be investigated in average and obese subjects. The effectiveness of such a protocol for long term weight control should be evaluated.

6. The mechanisms underlying EPOC need further investigation.

APPENDIX A

INFORMED CONSENT FORMS

Exercise Physiology Laboratory
University of Nevada, Las Vegas

Informed Consent Form

Title: The Combined Thermic Effect of Food, Continuous, and Intermittent Exercise

A strong interest in the effect of exercise training and single exercise bouts on resting metabolic rate and the thermic effect of a meal has developed over recent years. The question if an exercise bout causes a sustained elevation of resting metabolic rate after the completion of the exercise is currently being investigated. The answer to this question could have major implications for people who are trying to lose weight, since calories would not only be burned during exercise, but also during the recovery period. The general purpose of this study is to give a better understanding of resting metabolic rate, the thermic effect of exercise, and the thermic effect of a meal and their inter-relationship in five young, healthy, lean and fit women.

All subjects will report to the UNLV Exercise Physiology Laboratory for a preliminary meeting with a registered dietitian, who will explain the use of a diary for dietary analysis. Each subject's percent body fat (using hydrostatic weighing) and VO_2 max (maximal treadmill run) will then be determined. Procedures and special instructions will also be explained to the subject at that time. Each subject will then go through a series of six non-consecutive days of testing in a randomized order.

Day 1) A 9 hour measurement of resting metabolic rate (fasted)*
Day 2) Resting metabolic rate with one liquid test meal (10 kilocalories per kilogram of fat free body weight) to determine the thermic effect of a meal. **
Day 3) Same as Day 1 with one 45 minute exercise bout to determine the thermic effect of exercise.
Day 4) Same as Day 3 with a liquid meal after the exercise bout to determine the combined thermic effect of exercise and a meal.**
Day 5) Same as Day 1 with three - 15 minute exercise bouts at three hour intervals.
Day 6) Same as Day 5 with a liquid meal between bout 1 and 2.**

*Day 1 will be the first day of testing for each subject.
**The meals on days 2, 4, and 6 will be consumed at the same time during the day.

The metabolic rate will require the subject to breath through a mouthpiece and flexible hose apparatus for 5 minutes each half-hour in order to collect and analyze expired air. Heart rate will be measured during exercise testing.

All subjects will have been medically cleared for exercise. Testing will be supervised and monitored. Laboratory personnel will attempt to ensure safe exercise and laboratory surroundings.

Subject confidentiality will be maintained by keeping all data in safe keeping. Names, addresses, and telephone numbers will not be released without subject's permission. Only research personnel will have access to these files. You may refuse to participate in any part of this research study and you may withdraw at any time. Any questions you have regarding the study will be answered by Stefan Zander, Carrie Beithon, or Dr. Lawrence Golding

This study partially fulfills the requirements of the M.S. degree in Exercise Physiology for Stefan Zander.

Your signature below indicates that you have decided to volunteer as a research subject and that you have read the information provided.

DATE__________
PARTICIPANT SIGNITURE____________________________________
PRINT NAME____

DATE__________
WITNESS SIGNITURE_______________________________________
PRINT NAME____

INFORMED CONSENT

UNDERWATER WEIGHING

Underwater weighing is a procedure for determining the amount of fat in the body. The test involves dressing in a swim suit and wearing a canvas vest with weights in it's pockets giving the vest a weight of approximately 45 lbs. Dressed in this fashion the subject climbs in a tank 5 x 4 x 3 filled with water to the depth of 3 1/2 feet. The subject sits in the tank on a platform; the water is warm (96) and is up to the subject's chin. The weighted jacket insures that the subject won't float. The nose is clipped shut. Handles are located on the sides of the platform for the subject to hold on to. After exhaling completely the subject leans forward until the head is completely submerged; the weight is then recorded and the subject can sit up and clear the surface. This submerging takes about 10 seconds. This procedure is repeated 10 times. At anytime the subject can sit up and get his head clear of the water. The test is non-stressful and has virtually no risks involved in its administration. The possibility of slipping or falling, climbing in and out of the tank, is always possible, but care is taken to prevent this kind of accident. Non swimmers can be tested with no difficulty and the only persons who may have difficulty taking the test are individuals who are frightened of putting their face and head in the water.

In signing this consent form you indicate that you have read the above and understand what is expected of you. Any questions you had have been answered to your satisfaction and you enter the test voluntarily. You may at any time withdraw from the testing.

______________________	____________________/________
Subject's Name Printed	Subject's Signature / Date
______________________	____________________/________
Witness' Name Printed	Witness Signature / Date

INFORMED CONSENT

MAXIMAL OXYGEN UPTAKE

Test: The test you are about to take is to determine maximal oxygen uptake. This test involves working at a submaximal level, while heart rate is taken and expired breaths are analyzed. Each few minutes the workload is increased until maximum heart rate is attained. (This means that although the workload is increased, the heart rate does not increase.) This is about the point of maximum oxygen uptake.

This test requires you to work at your maximum ability and, therefore is a demanding, vigorous, and stressful test. Depending on your physical fitness, the test will last between 9-20 minutes. This test should only be taken by those who have been cleared by a physician who has indicated that there is no contraindication to the required stress. There are discomforts and possible dangers to the test. Muscle soreness, nausea, breathlessness, dizziness, and lightheadedness may occur. There is the possibility of falling or tripping on the treadmill. Maximum care, supervision, and preparation will be taken to minimize any hazard or danger. The test will be stopped any time the subject is not adapting well to the activity or when any major discomfort arises. The subject may stop the testing or withdraw from the test at any time. The test may be fatal for an individual with any history or symptoms of coronary artery disease.

In signing the consent form, I acknowledge that I understand the test procedure, the possible dangers, and certify that I have been medically examined and that there is no medical reason why I should not participate in the test.

______________________	______________________	__________
Subject's Signature	Subject's Name (printed)	Date
Witness' Signature	Witness' Name (printed)	Date

____

Witness' Address

APPENDIX B

WEIGHT-DIET-
AND EXERCISE HISTORY

DIET BY DESIGN

Nutritional Practices Questionaire

Name ____ Age ______
Last First Middle

Address ____
Street City State Zip

Weight ____________ Height ____________ Sex ___M___F Pregnant?______ Breastfeeding?______
Pounds Ounces Feet Inches

Occupation ______________________________ S.S. Number ____________

1. If you are currently or have been in the past on a special diet, please indicate by checking the appropriate box.

- ☐ Calorie restricted diet
- ☐ Diabetic diet
- Sodium restricted diet
- ☐ *Fat controlled diet*
- ☐ Low cholesterol diet
- ☐ High calorie diet
- ☐ Hypoglycemic
- ☐ Other ____________

2. **Has your appetite changed over the past three months?** ______ **Yes** ______ **No**
If yes, please explain.

____

____

3. **Has your weight increased or decreased more than 5 pounds in the last year?**
______ Yes ______ No Please Circle: Increase Decrease

4. **Please list vitamin and/or mineral supplement(s) taken on a daily basis:**

Supplement **Amount**

1. ____
2. ____
3. ____

5. **Please list medicines you take on a regular basis.**

Common Name **Chemical Name** **Dose** **How Many Times a Day?**

1. ____
2. ____
3. ____
4. ____

6. **If you have been medically diagnosed as having a chronic illness, please list the illness(es):**

1. ____
2. ____
3. ____
4. ____

continued...

7. **Do You Smoke Cigarettes?** _____ Yes _____ No   Number of cigarettes per 24 hours _____

8. **How often do you drink alcoholic beverages?**
   ☐ Daily   ☐ Several times a week   ☐ Seldom   ☐ Never

9. **Who prepares your meals?**
   ☐ Self   ☐ Spouse   ☐ Other__________

10. **How many times a week do you eat in a restaurant?**
   _______ Breakfast _______ Lunch _______ Dinner

11. **What kind of nutrition information would be most helpful to you?**

   ____

12. **It is most helpful if you can indicate your activity level over a typical 24 hour period of time.**

	Time (hours & Minutes)
Sleeping and/or reclining:	
Very Light: sitting, standing, driving, typing, studying, school work, playing musical instruments, painting, yoga, sewing, ironing, labwork, computer work, office work	
Light: low to moderate levels of exercise, bowling, softball, cooking, golf, sailing, walking 2.5 — 3 mph, electrical, carpentry, garage work, tailoring, pressing, general housework, light industrial work	
Moderate: jogging, dancing, skating, volleyball, badminton, racquetball, downhill skiing, tennis, walking 3.5 — 4 mph, weeding, gardening, scrubbing floors, loading and stacking objects, plastering, mowing, calisthenics, factory work	
Heavy: basketball, swimming, climbing, football, digging, walking with a load uphill, working with pick and shovel, running, bicycling, rowing, cross country skiing, aerobics, weight-lifting	
Total: (must equal 24 hours)	

Name:________________ Phone # in case there is a question:______________

Age: ________

Height: _______ Weight__________

Directions: Please record all food and drink consumed for three typical days- 2 school days and one off day. Try not to record days that are atypical-parties, etc. Record the type of food, how it was prepared, and the portion. Remember to include everything, such as cream and sugar in coffee, margarine on toast,etc. Please use a separate sheet for each day and staple them together. If eating out, please list the name of the restaurant.

Food	Amount	How Prepared	Time Eaten	Place
orange juice	4 ounces	frozen concentrate	8:00 am	home
quarter pounder	one	at McDonalds	noon	McDonalds
orange roughy	3 ounces	baked with 1 tsp of margarine	5:00 pm	at friend's
salad	1 cup	iceberg lettuce, 1 tomato, 2 slices cucumber, 10 croutons		
salad dressing, ranch	2 tbsp			

Exercise History

NAME ____________________________ **DATE** _______

Current Exercise Habits:

What are your current exercise habits?

How many times per week to you participate in aerobic exercise?

How many hours per week do you exercise aerobically?

Do you participate in any other acivities (ie. weight training, racquet sports, softball, etc.)? If yes, how many times per week do you engage in these activities? How many total hours per week?

Recent Exercise Habits: (0 - 2 years)

Have your exercise habits been consistent over the past 2 years?

If your habits have changed in the past 2 years, please describe the changes.

Past Exercise Habits: (2 + years)

Describe any special conditions concerning your exercise habits from 2 - 10 years past. (specific training, time off from exercise, etc.)

APPENDIX C
UNDERWATER WEIGHING
PROCEDURE

Underwater Weighing Procedure

1. The subject's residual volume was determined as described in Appendix G.

2. A noseclip was securely applied to the subject.

3. The subject was instructed to maximally exhale, while slowly lowering her head into the water, until it was completely submerged.

4. After a maximal exhalation, while completely submerged, weight was recorded six times with a digital printer.

5. A signal was given to the subject to surface.

6. Each subject performed 10 trials. For calculation purposes, only the last four trials were used. The high and low readings of each trial were neglected and the middle four were averaged. The four "trial averages" were then averaged again to come up with a final average underwater weight.

APPENDIX D

PRE-TEST

SUBJECT REMINDERS

Subject Reminders

No strenuous exercise 36 hours prior to each testing day.

No food or drink after 8:00 p.m. the evening before each testing day. (only water)

Maintain regular eating patterns throughout the duration of the study.

Avoid stressful situations on the morning of testing days.

Allow yourself time to get to the lab - don't hurry.

During testing, activity must be kept to a minimum - reading, watching t.v., writing, resting (no sleeping).

During testing, only water can be consumed.

APPENDIX E

24 HOUR RECALL QUESTIONNAIRE/
GENERAL QUESTIONNAIRE

Questionnaire

NAME ________________________________

DATE ______________

<u>24 Hour recall questions:</u>

1. How many hours did you sleep last night?

2. How long has it been (hours) since you last ate?

3. Have you had any major problems or pressures in the past 24 hours?

<u>General questions:</u>

1. Are you taking any medication? yes( ) no ( )
   If yes, indicate the name and type.

2. What was the date of the first day of your last menstrual cycle?

APPENDIX F
VISTA METABOLIC SYSTEM
INSTRUCTIONS

VISTA METABOLIC SYSTEM

Unit A: Upper unit with gas analyzers. Unit has the flow meters
Unit B: Lower unit with O2 and CO2 readouts
Computer: Hard drive and floppys
CRT: Screen
Printer

Unit B is left turned on all of the time, unless it is not going to be used for a long time.

1. Turn on Unit A. Needs a minimum of 20 mins. to warm-up

2. If needed change the drierite. (when drierite is saturated it turns purple)

3. Make sure the O2 & CO2 flow meters are between the red marks.
(Caution:Adjusting nobs very sensitive.)

4. Turn on computer & CRT.

5. VTXL comes up on screen after entering date & time.(24hr day)
(eg. 3:28 pm = 15:28)
(Anytime the program gets stuck on an A>, type in VTXL then <return>.

6. Before starting, check the amount of space on the data disk.
4 on the Menu: **Review results**, then:

   File Utilities, then:

   Memory (3) Space, <enter>.
   That will give the amount that has been used and the amount remaining. Ask for B drive.
   If new disk needed put in bottom

7. Return to main menu <escape>.

8. Go to **Calibration (No.2 on menu)** <return>. Got a calibration menu.

9. **Volume**.<return> (Note: Need a calibrated 3 liter syringe. Direct hook-up with connecting rubber tube,no valve).

   Sub-menu-1-2-3. **Turbine** <return>

   Size: put in 3 liters. Pull syringe handle out then hit any key.

   Push in syringe & check reading, repeat if necessary, OK if difference is .02 or less. Hit <return> Sub-menu asks:
   "kind of meter" select:**Turbine**...<return>
   "size of syringe" type in 3 liters,<enter>,
   suck out full syringe; and hit any key,.push in syringe.

Screen tells you what to do. Hit <enter>, hit any key, now internally calibrated. Check one more time..pull syringe out, hit any key push in, should check out. Go back to main menu <escape or item> and go on to Oxygen

11. Oxygen. <return> Get O2 cal.Menu. Don't adjust Unit B's readings unless absolutely necessary.
Connect Cal gas to the Cal port.
Open valve. Press Cal button on front panel & adjust the flow to the red lines by adjusting regulator valve on calibration gas tank.
Oxygen <R> O2 Cal.Menu.
1. Select 2 for High Span Gas, put in 2 and enter gas % from calibration tank. e.g. 15%

2. Observe analyzers & adjust span to read 15% when reading stable (gas & voltage-approx. 2.964) hit any key.

3. **Dont go to main menu**--Select item 2 gas calibrate, go to Air item (3) enter 20.93% unless already there.
Turn cal gas off (Button on front panel)
Wait until reading stable (gas & Voltage-4.149)
Hit any key.
<Escape> to menu and go'on to CO2 calibration.

11. Select CO2 on menu <enter>. High Span (2)
Turn cal gas on Front panel.
Enter % CO2 from calibrated gas tank. eg. 5%<return>
Stabilize and adjust CO2 (gas analyzer)
Hit any key when stable.
Turn Cal button off on front panel Select # Air
Enter % <return>
Hit any key when stable
<Escape>
Turn off cal gas.

13 Humidity. "Enter humidity .. put in 100% for expired air. <enter>

14. Temperature. Enter. lift lid on Unit A read thermometer in turbine and put in temperature. (Manual) then <enter>.

15 Pressure. enter get barometric pressure from wall barometer and put in. (Manual)

16. Go to "save calibration" and <Enter>.

17. <Escape> to main menu

18. **Perform test (3)** <enter>. fill in everything. (*must fill in everything.)* <escape>. (protocol 0)

19 Perform test **are you ready** Y/N one window. Selected parameters. Subject hooked up and ready.. Space bar changes choices. Ready "Yes" <enter>

20. PRESS ANY KEY TO START. DONT HIT KEY BEFORE 30 (on time elapsed) . BELT RUNNING When ready hit start test at same time as start test is hit on treadmill (Quinton). test going and ignore, even during recovery. finally finish test and then hit escape BUT DONT HIT ESCAPE WHILE IT IS COMPUTING DATA OR WILL LOOSE EVERYTHING ***DONT HIT ESCAPE BETWEEN 29-32*** (or between 59 - 02)

21. GO TO PRINT REPORT..<RETURN> no graphic printout and then <return>

APPENDIX G

RESIDUAL VOLUME PROCEDURE

METHOD

Description

A 5-liter anaesthesia bag was flushed three times and filled with 5 liters of 100% oxygen. Attached to one end of the bag was a standard 2-way syringe stopcock. The other end was fitted to the bottom part of a "T" shaped three-way valve. A standard mouthpiece was attached to the base of the "T" valve which was open either to air, through the other end of the "T" valve, or to the breathing bag. (See Figure 1)

All tests were conducted in the sitting position, with the subject inclined slightly forward. After explaining the procedure to the subject, a nose clip was secured firmly on the nose and the mouthpiece positioned properly in the mouth. After several breaths through the end of the "T" valve opened to room air, the subject was instructed to perform a maximal expiration to the point of his or her vital capacity, and to cap the end of the valve at this point with the palm of his or her hand. The subject was repeatedly encouraged to attain a full maximal expiration prior to capping the end of the valve. Once the end of the valve was capped, the experimenter turned the handle of the valve to the position when the subject was now connected to the 5-liter bag of oxygen. At this point, the subject was told to take 5-7 deep breaths from the bag at a rate of about one cycle/2 seconds. The rate and depth of breathing are critical to obtaining a proper mixing of respiratory gasses in the bag and lung to assure the attainment of a representative equilibrium value.

Following the 5-7 deep breaths, the subject was again told to exhale to maximal expiration, at which point the handle of the value was turned shutting off the 5-liter bag and opening that section of the valve allowing the subject to breathe room air. Then the 5-liter bag was deflated by approximately 1-liter, the remaining contents mixed, and then analyzed for O_2 and CO_2 by a Beckman Metabolic Measurement Cart (MMC), or by any other combination of O_2 and CO_2 analyzers. To calculate the residual volume, the following equation was used.

$$RV = VO_2 \times \frac{b - a}{c - d}$$

where:

RV = residual volume

VO_2 = volume of oxygen in the bag at the beginning of the procedure (5-liters)

a = percent nitrogen impurity of the original pure oxygen (assumed to be 0.0 for practical purposes)

b = percent of nitrogen in the mixed air in the bag at the point of equilibrium (100% - (%O_2 + %CO_2)

c = percent nitrogen in the alveolar air at the beginning of the test (assumed to be 80.0%)

d = percentage of nitrogen in the alveolar air during the last maximal breath. (assumed to be 0.2% N_2 higher than the equilibration percentage, i.e., b + 0.2% N_2)

APPENDIX H
RAW DATA-
VO_2 MEASUREMENTS

Resting Metabolic Rate (Control Day) - VO_2 Measurements

Time	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
7:30	0.262	0.218	0.212	0.252	0.250	0.239
7:45	0.262	0.218	0.208	0.252	0.225	0.233
8:00	0.242	0.230	0.208	0.220	0.225	0.225
8:30	0.285	0.230	0.247	0.203	0.225	0.238
9:00	0.265	0.218	0.213	0.222	0.215	0.227
9:30	0.243	0.215	0.223	0.227	0.226	0.227
10:00	0.258	0.225	0.220	0.228	0.232	0.233
10:30	0.248	0.175	0.213	0.238	0.193	0.213
11:00	0.207	0.212	0.218	0.242	0.222	0.220
11:30	0.275	0.198	0.225	0.220	0.227	0.229
12:00	0.232	0.182	0.208	0.225	0.205	0.210
12:30	0.253	0.210	0.307	0.228	0.245	0.249
13:00	0.287	0.230	0.235	0.223	0.177	0.230
13:30	0.247	0.220	0.235	0.212	0.240	0.231
14:00	0.235	0.212	0.215	0.230	0.220	0.222
14:30	0.272	0.202	0.245	0.233	0.212	0.233
15:00	0.258	0.223	0.233	0.262	0.212	0.238
15:30	0.225	0.247	0.233	0.243	0.232	0.236
16:00	0.245	0.230	0.248	0.258	0.240	0.244
16:30	0.277	0.235	0.233	0.242	0.228	0.243
17:00	0.302	0.260	0.230	0.248	0.277	0.263
Mean	0.256	0.219	0.231	0.232	0.224	0.232
SD	0.024	0.020	0.022	0.015	0.021	0.012
Mean+1SD	0.280	0.239	0.253	0.247	0.245	

Thermic Effect of a Standard Liquid Meal - VO_2 Measurements

	Time	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
	7:30	0.262	0.293	0.233	0.265	0.205	0.252
	7:45	0.255	0.207	0.268	0.235	0.205	0.234
	8:00	0.273	0.213	0.222	0.222	0.205	0.227
	8:30	0.282	0.258	0.248	0.257	0.238	0.257
	9:00	0.292	0.255	0.255	0.238	0.232	0.254
Meal	9:30	0.287	0.248	0.220	0.250	0.245	0.250
	10:00	0.297	0.300	0.298	0.272	0.237	0.281
	10:15	0.298	0.275	0.300	0.268	0.242	0.277
	10:30	0.278	0.217	0.267	0.270	0.233	0.253
	10:45	0.277	0.198	0.257	0.263	0.245	0.248
	11:00	0.287	0.232	0.267	0.298	0.245	0.266
	11:15	0.287	0.208	0.245	0.278	0.258	0.255
	11:30	0.335	0.207	0.262	0.270	0.238	0.262
	12:00	0.293	0.215	0.283	0.278	0.248	0.259
	12:30	0.298	0.215	0.233	0.262	0.242	0.250
	13:00	0.277		0.230	0.238	0.228	0.243
	13:30	0.318			0.255	0.213	0.261
	14:00	0.280					0.280

Thermic Effect of a 45 min Exercise Period and Its EPOC - VO_2 Measurements

	Time	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
	7:30	0.260	0.238	0.248	0.265	0.218	0.246
	7:45	0.232	0.238	0.232	0.237	0.233	0.234
Start Exercise	8:00	2.680	2.040	1.805	2.192	1.765	2.096
	8:20	2.600	2.120	1.925	2.363	1.825	2.207
	8:40	2.470	2.170	2.000	2.400	1.857	2.179
End Exercise	8:45	0.686	0.640	0.568	0.764	0.523	0.640
	9:00	0.298	0.273	0.308	0.330	0.250	0.292
	9:15	0.247	0.273	0.280	0.297	0.230	0.265
	9:30	0.253	0.273	0.247	0.287	0.258	0.264
	9:45	0.288	0.212	0.225	0.303	0.230	0.252
	10:00	0.300	0.215	0.287	0.268	0.238	0.262
	10:15	0.255	0.218	0.310	0.295	0.231	0.262
	10:30	0.268	0.225	0.247	0.283	0.215	0.248
	11:00	0.280	0.218	0.273	0.265	0.245	0.256

Thermic Effect of a 45 min Exercise Period and Its EPOC Preceding a Standard Meal - VO_2 Measurements

	Time	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
	7:30	0.257	0.213	0.250	0.218	0.212	0.230
	7:45	0.302	0.228	0.263	0.233	0.213	0.248
Start Exercise	8:00	2.760	2.040	1.777	2.160	1.757	2.099
	8:20	2.940	2.280	1.955	2.300	1.748	2.245
	8:40	2.982	2.270	1.960	2.320	1.775	2.261
End Exercise	8:45	0.784	0.617	0.607	0.533	0.563	0.617
	9:00	0.375	0.352	0.328	0.282	0.257	0.319
	9:15	0.295	0.315	0.290	0.282	0.247	0.288
	9:30	0.275	0.237	0.262	0.242	0.235	0.250
Meal	9:45	0.260	0.282	0.245	0.262	0.253	0.260
	10:00	0.327	0.310	0.305	0.288	0.232	0.292
	10:15	0.362	0.287	0.270	0.262	0.235	0.283
	10:30	0.327	0.290	0.307	0.253	0.243	0.284
	10:45	0.313	0.302	0.258	0.258	0.226	0.271
	11:00	0.327	0.310	0.288	0.282	0.270	0.291
	11:15	0.347	0.262	0.283	0.275	0.277	0.289
	11:30	0.312	0.267	0.277	0.275	0.253	0.277
	12:00	0.302	0.240	0.262	0.270	0.248	0.264
	12:30	0.298	0.180	0.265	0.190	0.243	0.235
	13:00	0.292	0.225	0.227		0.215	0.240
	13:30	0.230		0.235		0.218	0.228
	14:00	0.255					0.255

Thermic Effect of Three 15 min Exercise Periods and Their EPOC with a Standard Meal between Period One and Two - VO_2 Measurements

	Time	Subject 1	Subject 2	Subject 3	Subject 4	Average
	7:30	0.285	0.218	0.207	0.290	0.250
	7:45	0.275	0.218	0.218	0.230	0.235
Start Exercise	8:00	2.890	2.285	1.850	2.280	2.326
	8:10	3.015	2.370	1.885	2.390	2.415
End Exercise	8:15	0.560	0.642	0.537	0.528	0.567
	8:30	0.303	0.278	0.270	0.287	0.285
	8:45	0.277	0.268	0.270	0.260	0.269
	9:00	0.317	0.245	0.238	0.247	0.262
	9:15	0.288	0.227	0.262	0.233	0.253
	9:30	0.293	0.228	0.247	0.268	0.259
Meal	10:00	0.322	0.253	0.280	0.298	0.288
	10:15	0.345	0.248	0.272	0.295	0.290
	10:30	0.317	0.285	0.257	0.295	0.289
	10:45	0.377	0.252	0.252	0.300	0.295
Start Exercise	11:00	2.952	2.100	1.830	2.180	2.266
	11:10	3.110	2.370	1.970	2.210	2.415
End Exercise	11:15	0.805	0.641	0.516	0.508	0.618
	11:30	0.392	0.332	0.265	0.300	0.322
	11:45	0.393	0.340	0.300	0.253	0.322
	12:00	0.368	0.335	0.290	0.277	0.318
	12:15	0.290	0.275	0.272	0.280	0.279
	12:30	0.288	0.250	0.257	0.258	0.263
	13:00	0.287	0.277	0.268	0.278	0.278
	13:30	0.340	0.343	0.237	0.298	0.305
Start Exercise	14:00	3.050	2.165	1.760	2.147	2.286
	14:10	3.172	2.340	1.930	2.235	2.419
End Exercise	14:15	0.734	0.665	0.401	0.557	0.589
	14:30	0.327	0.335	0.233	0.215	0.278
	14:45	0.307	0.270	0.248	0.197	0.256
	15:00	0.317	0.180	0.250	0.200	0.237
	15:15	0.305	0.180	0.242		0.242
	15:30	0.298		0.222		0.260
	16:00	0.287				0.287

Thermic Effect of Three 15 min Exercise Periods and Their EPOC - VO_2 Measurements

	Time	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average
	7:30	0.228	0.232	0.202	0.212	0.208	0.216
	7:45	0.238	0.202	0.248	0.212	0.208	0.222
Start Exercise	8:00	2.952	1.980	1.780	2.158	1.863	2.147
	8:10	2.830	2.120	1.910	2.335	1.813	2.202
End Exercise	8:15	0.610	0.566	0.508	0.547	0.552	0.557
	8:30	0.283	0.293	0.308	0.250	0.252	0.277
	8:45	0.268	0.242	0.327	0.235	0.227	0.260
	9:00	0.275	0.183	0.230	0.233	0.255	0.235
	9:15	0.237	0.207	0.258	0.210	0.257	0.234
	9:30	0.252	0.226	0.213	0.208	0.245	0.229
	10:00	0.225	0.271	0.243	0.217	0.270	0.245
	10:30	0.252	0.225	0.227	0.207	0.258	0.234
Start Exercise	11:00	2.832	1.990	1.730	2.680	1.825	2.207
	11:10	2.948	2.150	1.840	2.850	1.918	2.341
End Exercise	11:15	0.610	0.572	0.491	0.648	0.587	0.582
	11:30	0.352	0.260	0.290	0.323	0.258	0.297
	11:45	0.307	0.197	0.297	0.267	0.270	0.268
	12:00	0.252	0.193	0.247	0.267	0.280	0.248
	12:15	0.297	0.232	0.223	0.260	0.282	0.259
	12:30	0.277	0.215	0.225	0.273	0.260	0.250
	13:00	0.262	0.225	0.243	0.313	0.267	0.262
	13:30	0.347	0.305	0.310	0.250	0.260	0.294
Start Exercise	14:00	2.912	2.030	1.730	2.053	1.867	2.118
	14:10	2.962	2.110	1.810	2.150	1.923	2.191
End Exercise	14:15	0.699	0.597	0.475	0.449	0.584	0.561
	14:30	0.292	0.253	0.265	0.243	0.278	0.266
	14:45	0.313	0.192	0.300	0.257	0.253	0.263
	15:00	0.317	0.163	0.290	0.225	0.220	0.243
	15:15	0.282	0.245	0.263	0.228	0.213	0.246
	15:30	0.273		0.233			0.253
	16:00	0.282					0.282

BIBLIOGRAPHY

Acheson, K., Jequier, E., & Warren, J. 1983. Influence of beta-adrenergic blockade on glucose-induced thermogenesis in man. Journal of Clinical Investigation in Man. 72, 981-986.

Acheson, K.J. 1987. Obesity and thermogenesis in man. Diabetes/ Metabolism Reviews. 13(5), 549-53.

Aschoff, J. & Pohl, H. 1970. Rhythmic variations in energy metabolism. Federation Proceedings. 29,1541-1552.

Åstrand, P.O. & Rodahl, K. 1977. Textbook of work physiology. New York: McGraw-Hill

Astrup, A., Anderson, T., Henriksen, O., Christensen, N.J., Bulow, J., Madsen, J., & Quaade, F. 1987. Impaired glucose-induced thermogenesis in skeletal muscle in obesity. The role of the sympathetic system. International Journal of Obesity, 11(1), 51-66.

Atwater. W. O. & Benedict, F.G. 1903. Experiments on the metabolism of matter and energy in the human body. U.S. department of Agriculture Official Experimental Station Bulletin. 136(1),357.

Bahr, R. & Maehlum, S. 1986. Excess post-exercise oxygen consumption. A short review. Acta Physiologica Scandinavica. 556, 99-104.

Bahr, R., Ingnes, I., & Vaage, O. 1987. Effect of duration of exercise on excess post-exercise consumption. Journal of Applied Physiology. 62, 485-490.

Beithon, C. 1991. Resting metabolic rate of female college students. Unpublished manuscript. University of Nevada, Exercise Physiology Laboratory, Las Vegas.

Belko, A.Z. 1987. Diet, exercise, weight loss, and energy expenditure in moderately overweight women. International Journal of Obesity. 11(2), 93-104.

Benedict, F.G. & Milner, R.D. 1907. Experiments on metabolism of matter and energy in the human body. USDA, Office of Experimental Stations, Bulletin, 175, 1903-1904.

Benedict, F.G. & Sherman, H.C. 1937. Basal metabolism of rats in relation to old age and exercise during old age. Journal of Nutrition, 14, 179-198.

Bielinski, R., Schutz, Y., & Jequier, E. 1985. Energy metabolism during the postexercise recovery in man. American Journal of Clinical Nutrition, 42(1), 69-82.

Bingham, S.A., Goldberg, G.R., Coward, W.A., Prentice, A.M., & Cummings, J.H. 1989. The effect of exercise and improved physical fitness on basal metabolic rate. British Journal of Nutrition, 61(2), 155-73.

Blaza, S. 1983. Thermogenic response to temperature, exercise and food stimuli in lean and obese women, studied by 24 hour direct calorimetry. British Journal of Nutrition, 49(2),171-80.

Blom, P.C., Vollestad, N.K., & Costill, D.L. 1986. Factors affecting changes in muscle glycogen concentration during and after prolonged exercise. Acta Physiologica Scandinavica Suppl, 556, 67-74.

Blondheim, S.H. & Hirt, R. 1982. Relationship between dietary thermogenesis and bulk of meal. Journal of Medical Science, 18(9), 969-71.

Bogardus, C. & Lillioja, B.C. 1986. Familial dependence of the resting metabolic rate. New England Journal of Medicine, 315, 96-100.

Bogert, L.V., Briggs, G.M., & Calloway, D.H. 1973. Nutrition and physical fitness (9th ed.). Philadelphia: W.B. Saunders

Boothby, W.M., Berkson, J., & Dunn, H.L. 1936. Studies of energy metabolism of normal individuals: a standard for basal metabolism, with a nomogram for clinical application. American Journal of Physiology, 11(6), 468-484.

Booyens, J. & McCance, R.A. 1957. Individual variations in expenditure of energy. The Lancet, 225-229.

Bray, G.A. 1974. The acute effects of food intake on energy expenditure during cycle ergometry. American Journal of Clinical Nutrition, 27, 254-9.

Brehm, B.A. 1988. Elevation of metabolic rate following exercise: implications for weight loss. International Journal of Sports Medicine, 6, 72-78.

Brehm, B.A. & Gutin, B. 1986. Recovery energy expenditure for steady state exercise in runners and nonexercisers. Medicine and Science in Sports and Exercise, 18, 205-210.

Burzstein, S., Elwyn, D.H. Askanzi, J., & Kimmey, J.M. 1989. Energy metabolism, indirect calorimetry and nutrition. Baltimore: Williams and Williams

Calloway, D.H., & Zami, E. 1980. Energy requirements and energy expenditure of elderly men. The American Journal of Clinical Nutrition, 33, 2088-2092.

Carpenter, T.M. 1948. Tables, factors and formulas for computing respiratory exchange and biological transformation of energy (4th ed.). Washington, D.C.: Carnegie Institution of Washington, Publication 303C.

Chad, K.E. & Wenger, H.A. 1988. The effect of exercise duration on the exercise and postexercise oxygen consumption. Canadian Journal of Sports Science, 13(4), 204-7.

Consolazio, C.F., Johnson, R.E., & Pecora, L.J. 1963. Physiological measurements of metabolic functions in man. New York: McGraw-Hill

D'Alessio, D.A., Bushman, M.C., Mozzoli, M.A., Smalley, K.J., Polansky, M., Knedrick, Z.V., Owen, L.R., Bushman, M.C., Boden, G., & Owen, O.E. 1988. Thermic effect of food in lean and obese men. Journal of Clinical Investigation, 81(6), 1781-9.

Dagenais, G.R. 1966. Hemodynamic effects of carbohydrate and protein meals in men: rest and exercise. Journal of Applied Physiology , 21, 1157-62.

Dallosso, H.M. & James, W.P.T. 1984. Whole-body calorimetry studies in adult men & the interaction of exercise and overfeeding on the thermic effect of a meal. British Journal of Nutrition, 52, 65-72.

Danforth, E. 1985. Diet and obesity. American Journal of Clinical Nutrition, 41, 1132-1145.

Davis, J.R., Tagliaferro, A.R., Kertzer, R. 1983. Variations in dietary-induced thermogenesis and body fatness with aerobic capacity. European Journal of Applied Physiology, 50, 319-329.

Devlin, J.T. & Horton, E.S. 1986. Potentiation of the thermic effect of insulin by exercise: differences between lean, obese and non-insulin Dependent Diabetic Men. American Journal of Clinical Nutrition, 43, 884-890.

Dohm, G.L. 1986. Metabolic responses to exercise after fasting. Journal of Applied Physiology, 61(4), 1363-1368.

DuBois, D. & DuBois, E.F. 1915. Clinical calorimetry: The measurement of the surface area of man. Archives of Internal Medicine, 15, 868-881.

Dudani, U., Bijlani, R.L., Gupta, M.C., Manocha, S., & Nayar, U. 1986. Metabolic rate at rest and after meals with varying fibre content in obese and nonobese women. Indian Journal of Medical Research, 84, 74-82.

Edwards, H.T., Thorndike Jr, A., & Dill, D.B. 1935. The energy requirement in strenuous muscular exercise. New England Journal of Medicine , 213, 532-535.

Elia, M., Lammert, O., Zed, C., & Neale, G. 1984. Energy metabolism during exercise in normal subjects undergoing total starvation. Human Nutrition: Clinical Nutrition, 38(5), 355-62.

Fong, P. 1963. Foundations of thermodynamics. New York: Oxford University Press.

Freedman-Akabas, S., Colt, E., & Kissileff, H.R. 1985. Lack of sustained increase in VO2 following exercise in fit and unfit subjects. American Journal of Clinical Nutrition, 41(3), 545-9.

Gaesser, G.A. & Brooks, G.A. 1984. Metabolic bases of excess post-exercise oxygen consumption: A review. Medicine and Science in Sports and Exercise, 16, 29-43.

Garby, L. & Lammert, O. 1977. Effect of the preceding day's energy intake on the total energy cost of light exercise. Acta Physiologica Scandinavica, 101(4), 411-7.

Garby, L. & Lammert, O. 1984. Within-subjects between-days-and weeks variation in energy expenditure at rest. Human Nutrition: Clinical Nutrition, 38(5), 395-7.

Garby, L., Garrow, J.S., Jorgensen, B., Lammert, O., Madsen, K., Sorenson, P. & Webster, J. 1988. Relation between energy expenditure and body composition in man: specific energy expenditure in vivo of fat and fat free tissue. European Journal of Clinical Nurtrition, 42(4), 301-5.

Garrow, J.S. 1986. Exercise, diet and thermogenesis. Current Concepts in Nutrition, 15, 51-65.

Gephart, F.C. & DuBois, E.F. 1915. The determination of the basal netabolism of normal men and the effect of food. Archives of International Medicine, 15, 835-867.

Gleeson, M., Brown, J.F., Waring, J.J., & Stock, M.J. 1979. The effects of exercise and exercise training on dietary induced thermogenesis. Proceedings of the Nutritional Society, 38(1), 8A.

Gleeson, M., Brown, J.F., Waring, J.J., & Stock, M.J. 1982. The effects of physical exercise on metabolic rate and dietary-induced thermogenesis. British Journal of Nutrition, 47(2), 173-81.

Golding, L.A., Myers, C.R., & Sinning, W.E. (Eds). 1989. Y's way to physical fitness (3rd ed.) Champaign: Human Kinetics.

Gustafson, F.L. & Benedict, F. G. 1929. The seasonal variation in basal metabolism. The American Journal of Physiology, 6, 43-58.

Guyton, A.C. 1986. Textbook of medical physiology (7th ed.). Philadelphia: W.B. Saunders

Hadley, M.E. Endocrinology (2nd ed.) 1988. Englewood Cliffs, New Jersey: Prentice Hall.

Haldane, J.S. & Priestly, J.G. 1935. Respiration. New York: Oxford University Press

Henry, C.J. & Emery, B. 1986. Effect of spiced food on metabolic rate. Human Nutrition: Clinical Nutrition, 40(2), 165-8.

Henson, L.C., Poole, D.C., Donahoe, C.P., & Heber, D. 1987. Effects of exercise training on resting energy expenditure during caloric restriction. American Journal of Clinical Nutrition, 46, 893-899.

Hermansen, L., Grandmortagne, M., Maehlum, S., & Ignes, I. 1984. Postexercise elevation of resting oxygen uptake: possible mechanisms and physiological significance. Physiological Chemistry of Training and Detraining. Basel: S. Karger

Hill, A.V., Long, C.N.H., & Pupton, H. 1924. Muscular exercise, lactic acid and the supply and utilization of oxygen Part 4. The recovery process after exercise in men, and Part 5. The oxygen debt at the end of exercise. Proceedings of the Royal Society, 97, 96-137.

Hill, J.O. 1984. Meal size and thermic response to food in male subjects as a function of maximum aerobic capacity. Metabolism, 33(8), 743-749.

Hill, J.O., Heymsfield, S.B., McMannus, C., & Digirolamo, M. 1984. Meal size and thermic response to food in male subjects as a function of maximum aerobic capacity. Metabolism, 33, 743-749.

Himms-Hagen, J. 1985. Brown adipose tissue metabolism and thermogenesis. Annual Review of Nutrition, 5, 69-94.

Himms-Hagen, J. 1976. Cellular thermogenesis. Annual Review of Physiology, 38, 315-51.

Himms-Hagen, J. 1984. Brown adipose tissue thermogenesis, energy balance and Obesity. Canadian Journal of Biochemistry and Cellular Biology, 62(7), 610-7.

Himms-Hagen, J. 1989. Role of thermogenesis in the regulation of energy balance in relation to obesity. Canadian Journal of Physiology and Pharmacology, 67(4), 394-401.

Horton, E.S. 1983. Introduction: an overview of the assessment and regulation of energy balance in humans. American Journal of Clinical Nutrition, 38(6), 972-977.

Horton, E.S. 1986. Metabolic aspects of exercise and weight. Medicine and Science in Sports and Exercise, 18(1), 10-18.

Hultman, E.H. 1986. Carbohydrate metabolism during hard exercise and in the recovery period after exercise. Acta Physiologica Scandinavica Suppl 556, 75-82.

James, W.P. & Trayhurn, P. 1981. Thermogenesis and obesity. British Medical Bulletin, 37(1), 43-8.

Jansson, E. 1982. On the significance of the respiratory exchange ratio after different diets during exercise in man . Acta Physiologica Scandinavica, 114(1), 103.

Jequier, E. 1983. Thermogenic responses induced by nutrients in man: their importance in energy balance regulation. Experientia Supplement, 44, 26-44.

Jequier, E. 1986. Thermogenesis and its role in energy metabolism. Bibliotheka Nutritio et Dieta, 39, 6-12.

Jequier, E. 1989. Energy metabolism in human obesity. Soziale Praventivmedizin, 34(2), 58-62.

Jequier, E. & Schutz, Y. 1983. Long term measurements of energy expenditure in humans using a respiration chamber. American Journal of Clinical Nutrition, 38(6), 989-998.

Jequier, E., & Schutz, Y. 1985. New evidence for a thermogenic defect in human obesity. International Journal of Obesity, 9 (Suppl. 2), 1-7.

Jones, W.B. 1965. Circulatory and ventilatory responses to postprandial exercise. American Heart Journal, 69, 668-676.

Kaerki, N.T. 1956. The urinary excretion of noradrenaline and adrenaline in different age groups, its diurnal variation, and the effect of muscular work on it. Acta Physiologica Scandinavia, Suppl., 132, 123-25

Katch, F.I. & McArdle, W.D. 1983. Nutrition, weight control and exercise (2nd ed.). Philadelphia: W.B. Saunders

Kelback, H. 1987. Autonomic nervous control of postpradinal hemodynamic changes at rest and upright exercise. Journal of Applied Physiology, 63, 1862-1865.

Knapik, J.J. 1988. Influence of fasting on carbohydrate and fat metabolism during rest and exercise in men. Journal of Applied Physiology, 64(5), 1923-9.

Koeslag, J.H. 1982. Post-exercise ketosis in the hormone response to exercise: a review. Medicine and Science in Sports and Exercise, 14(5), 327-34.

Lammert, O. & Hansen, E.S. 1982. Effects of excessive caloric intake and caloric restriction on body weight and energy expenditure at rest and light exercise. Acta Physiologica Scandinavica, 114(1), 135-141.

Lammert, O., Garby, L., Maron, K., Mork, G., Thein, M., Flindt-Egebak, P., & Krogh-Hansen, J. 1987. Effect of the preceding day's energy intake on the energy costs of rest, arm and leg exercise. Human Nutrition: Clinical Nutrition, 41(2), 141-7.

Lavoisier, A.L. & R.S. de La Place. 1940. Memoire sur la chaleur. Memories de l'Academie Royale 1789. Reprinted in Ostwald's Klassiker, Leipzig, 1892

LeBlanc, J., D' Sussault, J., Lupien, D., & Richard, D. 1982. Effect of diet and exercise on norepinephrine-induced thermogenesis in male and female rats. Journal of Applied Physiology, 52(3), 556-561.

LeBlanc, J., Diamond, P. Cote, J., & LaBrie, A. 1984. Hormonal factors in reduced postprandial heat production of exercise trained subjects. Journal of Applied Physiology, 56, 772-776.

LeBlanc, J., Jobin, M., Cote, J., Samson, P., & LaBrie, A. 1985. Enhanced metabolic response to caffeine in exercised-trained humans. Journal of Applied Physiology, 59, 832-837.

Leblanc, J. 1985. Thermogenesis in relation to feeding and exercise training. International Journal of Obesity, 9 (Suppl. 2), 75-9.

Leblanc, J. 1986. Thermogenesis with relation to exercise and exercise-training. Acta Physiologica Scandinavica, 711, 75-81.

Leblanc, J. & Brondel, L. 1985. Role of palatability on meal-induced thermogenesis in human subjects. American Journal of Physiology, 248(3 pt 1), 333-6.

Leblanc, J., Mercier, P., & Samson, P. 1984. Diet-induced thermogenesis with relation to training state in female subjects. Canadian Journal of Physiology and Pharmacology, 62(3), 334-7.

Leff, M. & Hill, J. 1989. Resting metabolic rate: measurement reliability. Journal of Parenteral and Enteral Nutrition, 11(4), 354-359.

Lohman, T.G., Roche, A.F., & Martorell, R. 1988. Anthropometric standardization reference manual. Champaign: Human Kinetics

Maehlum, S. Grandmontagne, M. Newsholme, E.A., & Sejersted, O.M. 1986. Magnitude and duration of excess postexercise oxygen consumption in healthy young subjects. Metabolism, 35(5), 425-429.

Maron, M.B., Horvath, S.M., & Wilkerson, J.E. 1977. Blood biochemical alterations during recovery from competative marathon running. European Journal of Applied Physiology, 36, 231-238.

McArdle, W.D., Katch, F.I., & Katch, V.L. 1981. Exercise physiology, energy, nutrition and human performance. Philadelphia: Lea and Febiger

McArdle, W.D., Katch, F.I., & Katch, V.L. 1986. Exercise physiology, energy, nutrition and human performance (2nd ed.). Philadelphia: Lea and Febiger

McDonald, R.B., Wickler, S., Horwitz, B., & Stern, J.S. 1988. Meal-induced thermogenesis following exercise training in the rat. Medicine and Science in Sports and Exercise, 20(1) Feb., 44-9.

Miller, D.S. 1982. Factors affecting energy expenditure. Proceedings of the Nutritional Society, 41(2), 193-202.

Morehouse, L.E. & Miller, A.T. 1963. Physiology of exercise (4th ed.). St. Louis: C.V. Mosby

Morgan, W.P. 1983. Psychometric correlates of respiration: A review. American Industrial Hygiene Association Journal, 44, 677-684.

Morgan, W.P. 1985. Psychogenic factors and exercise metabolism: a review. Medicine and Science in Sports and Exercise, 17(3), 309-16.

Morgan, W.P. 1983. Hyperventilation syndrome: A review. American Industrial Hygiene Association Journal, 44, 685-689.

Nair, K.S., Halliday, D., & Garrow, J.S. 1983. Thermic response to isoenergetic protein, carbohydrate or fat meals in lean and obese subjects. Clinical Science, 65(3), 301-312.

Nichols, J., Ross, S., & Patterson, P. 1988. Thermic effect of food at rest and following swim exercise in trained college men and women. Annals of Nutrition and Metabolism, 32(4), 215-9.

Nielsen, E. 1987. Acute modest changes in relative humidity do not affect energy expenditure at rest in human subjects. Human Nutrition: Clinical Nutrition, 41(6), 485-8.

Owen, O. E. 1988. Resting metabolic requirements of men and women. Mayo Clinical Proceedings, 63, 503-510.

Owen, O.E., Holup, M.L., & D'Allessio, D.A. 1987. A reappraisal of the caloric requirements of men. American Journal of Clinical Nutrition, 46, 875-885.

Owen, O.E., Kavle, E., & Owen, R.S. 1986. A reappraisal of caloric requirements in healthy women. American Journal of Clinical Nutrition, 44, 1-19.

Pacy, P.J., Barton, N., Webster, J.D., & Garrow, J.S. 1985. The energy cost of aerobic exercise in fed and fasted normal subjects. American Journal of Clinical Nutrition, 42(5), 764-8.

Passmore, P. & Johnson, R.E. 1960. Some metabolic changes following prolonged moderate exercise. Metabolism, 9, 452-456.

Pi-Sunyer, F.X. 1984. Thermogenesis in human obesity. Current Concepts in Nutrition, 13, 87-102.

Poehlman, E. T., & Horton E.S. 1989. The impact of food intake and exercise on energy expenditure. Nutrition Reviews, 47 (5), 129-137.

Poehlman, E.T. & Melby, C.L. 1989. Aerobic fitness and resting energy expenditure in young adult males. Metabolism, 38(1), 85-90.

Poehlman, E.T., Arciere, P.J., Melby, C.L., & Badylak, S.F. 1988. Resting metabolic rate and postprandial thermogenesis in vegetarians and nonvegetarians. American Journal of Clinical Nutrition, 48(2), 209-13.

Poehlman, E.T., Melby, C.L., & Badylak, S.F. 1988. Resting metabolic rate and postprandial thermogenesis in highly trained and untrained males. American Journal of Clinical Nutrition, 47(5), 793-8.

Poehlman, E.T., Despres, J.P., Bessette, H., Fontaine, E., Tremblay, A., & Bouchard, C. 1985. Influence of caffeine on the resting metabolic rate of exercise-trained and inactive subjects. Medicine and Science in Sports and Exercise, 17, 689-694.

Ravussin, E. 1985. Evidence that insulin resistance is responsible for the decreased thermic effect of glucose in human obesity. Journal of Clinical Investigation, 76, 1268-1273.

Ravussin, E. 1988. Reduced rate of energy expenditure as a risk factor for body weight gain. New England Journal of Medicine, 318, 467-472.

Ravussin, E., Burnand, B., Schutz, Y., & Jequier, E. 1982. Twenty-four hour energy expenditure and resting metabolic rate in Obese, moderately obese and control subjects. American Journal of Clinical Nutrition, 35(3), 566-573.

Ravussin, E., Lillioja, S. Anderson, T.E., Christin, L., & Bogardus, C. 1986. Determinants of 24-hour energy expenditure in man. Journal of Clinical Investigation, 78(6), 1568-78.

Richard, D. & Rivest, S. 1989. The role of exercise in thermogenesis and energy balance. Canadian Journal of Physiology and Pharmacology, 87(4), 402-9.

Roth, D.A., Stanley, W.C., & Brooks, G.A. 1988. Induced lactacidemia does not affect postexercise oxygen consumption. Journal of Applied Physiology, 65(3), 1045-1049.

Rothwell, N.J. & Stock, M.J. 1981. Regulation of energy balance. Annual Review of Nutrition, 1, 235-256.

Rubner, M. 1902. Die Gesetze des Energieverbrauches bei der Ernahrung. Leipzig, Deutiche.

Sameloff, S., Beer, G., & Blondheim, S.H. 1982. Influence of physical activity on the thermic effect of food in young men. Journal of Medical Science, 18(1), 193-6.

Scalfi, L., Coltorti, A., D'Arrigo. E., & Carandente, V. 1987. Effect of dietary fibre on postprandial thermogenesis. International Journal of Obesity, 11(Suppl. 1), 95-99.

Schwartz, R.S., Ravussin, E., Massari, M., O' Connell, M., & Robbins, D.C. 1985. The thermic effect of carbohydrate versus fat feeding in man. Metabolism, 34(3), 285-293.

Schneider, E.D. & Foster, A.O. 1931. The influence of physical training on the basal metabolic rate of man. American Journal of Physiology, 98, 595-601.

Scholander, P.F. 1947. Analyzer for accurate estimation of respiratory gases in one half cubic centimeter samples. Journal of Biology and Chemistry, 167, 235-250.

Schutz, Y., Bessard, T., & Jequier, E. 1984. Diet-induced thermogenesis measured over a whole day in obese and non-obese women. American Journal of Clinical Nutrition, 40(3), 542-52.

Schutz, Y., Bessard, T., & Jequier, E. 1987. Exercise and postprandial thermogenesis in obese women before and after weight loss. American Journal of Clinical Nutrition, 45(6), 1424-32.

Schutz, Y., Bray, G. & Margen, S. 1987. Postprandial thermogenesis at rest and during exercise in elderly men ingesting two levels of protein. Journal of the American College of Nutrition, 6(6), 497-506.

Segal, K.R. 1984. Thermic effect of food during graded exercise in normal weight and obese men . American Journal of Clinical Nutrition, 40, 995-1000.

Segal, K.R. & Gutin, B. 1983. Thermic effects of food and exercise in lean and obese women. Metabolism, 32(6), 581-9.

Segal, K.R. & Pi-Sunyer, F.X. 1986. Exercise, resting metabolic rate, and thermogenesis. Diabetes/Metabolism Reviews, 2(1-2), 19-34.

Segal, K.R., Gutin, B., & Nyman, A.M. 1985. Thermic effect of food at rest, during exercise, and after exercise in lean and obese men of similar body weight. Journal of Clinical Investigation, 76(3), 1107-12.

Segal, K.R., Gutin, B., Albu, J., & Pi-Sunyer, F.X. 1987. Thermic effects of food and exercise in lean and obese men of similar lean body mass. American Journal of Physiology, 252(1 pt 1), 110-7.

Segal, K.R., Lacayanga, I., Dunaif, A., Gutin, B., & Pi-Sunyer, F.X. 1989. Impact of body fat mass and percent fat on metabolic rate and thermogenesis in men. American Journal of Physiology, 256(5 pt. 1), 573-9.

Shah, M., Miller, D.S., & Geissler, C.A. 1988. Lower metabolic rates in post-obese versus lean women: thermogenesis, basal metabolic rate and genetics. European Journal of Clinical Nutrition, 42(9), 741-52.

Soares, M.J. 1986. Intra-individual variations in resting metabolic rates of human subjects. Human Nutrition: Clinical Nutrition, 40(5), 365-9.

Steiniger, J., Karst, H., Noack, R., & Steglich, H.D. 1987. Diet-induced thermogenesis in man: thermic effects of single protein and carbohydrate test meals in lean and obese subjects. Annals of Nutrition and Metabolism, 31(2), 117-25.

Stephenson, L.A., Kolka, M.A., & Wilkerson, J.E. 1982. Metabolic and thermoregulatory responses to exercise during the human menstrual cycle. Medicine and Science in Sports and Exercise, 14(4), 270-5.

Stock, M.J. 1980. Effects of fasting and refeeding on the metabolic response to a standard meal in man. European Journal of Applied Physiology, 43(1), 35-40.

Stock, M.J., Norgan N.G, Ferro-Luzzi, A., & Evans, E. 1978. Effect of altitude on dietary-induced thermogenesis at rest and during light exercise in man. Journal of Applied Physiology, 45(3), 345-9.

Suess, W.M., Alexander, A.B., Smith, D.D., Sweeny, H.W., & Marion, R.J. 1980. The effects of psychological stress on respiration: A preliminary study of anxiety and hyperventilation. Psychophysiology, 17, 535-540.

Tagliaferro, A.R., Kertzer, R., Davis, J.R., Janson, C., & Tse, S.K. 1986. Effects of exercise-training on the thermic effect of food and body fatness of adult women. Physiology and Behavior, 38(5), 703-10.

Thompson, J.K. 1987. Energy conservation and exercise dependence: a sympathetic arousal hypothesis. Medicine and Science in Sports and Exercise, 19(2), 91-99.

Thorne, A. & Wahren, J. 1989. Diet-induced thermogenesis in well-trained subjects. Clinical Physiology, 9(3), 295-305.

Tremblay, A., Cote, J., & Leblanc, J. 1983. Diminished dietary thermogenesis in exercise-trained human subjects. European Journal of Applied Physiology, 52(1), 1-4.

Tremblay, A., Fontaine, E., Poehlman, E.T., Mitchell, D., Perron, L., & Bouchard, C. 1986. The effect of exercise-training on resting metabolic rate in lean and moderately obese individuals. International Journal of Obesity, 2(3), 223-33.

Tremblay, A., Despres, J.P., & Bouchard, C. 1985. The effects of exercise-training on energy balance and adipose tissue morphology and metabolism. International Journal of Sports Medicine, 2(3), 223-33.

Tremblay, A., Fontaine, E., & Nadeau, A. 1985. Contribution of post exercise increment in glucose storage variations in glucose-induced thermogenesis in endurance . Canadian Journal of Physiology and Pharmacology, 63, 1165-1169.

Walsh, B.J. & Morely, T.F. 1989. Comparison of three methods of determining oxygen consumption and resting energy expenditure. Journal of American Osteopathic Association, 89(1), 43-46.

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

Welle, S. 1984. Metabolic responses to a meal during rest and low-intensity exercise. American Journal of Clinical Nutrition, 40(5), 990-994.

Willcutts, K.F. 1988. Energy metabolism during exercise at different time intervals following a meal. International Journal of Sports Medicine, 9(3), 240-3.

Woo, R., Daniels-Kush, R., & Horton, E.S. 1985. Regulation of energy balance. Annual Review of Nutrition, 5, 411-433.

Young, J.C. Treadway, J.L., Balon, T.W., Gavras, H.P. & Ruderman, N.B. 1986. Prior exercsie potentiates the thermic effect of a carbohydrate load. Metabolism, 35(11), 1048-53.

Zurlo, F., Schutz, Y., Frascarolo, P., Enzi, G., Deriaz, O., & Jequier, E. 1986. Variability of resting energy expenditure in healthy volunteers during fasting and continuous enteral feeding. Critical Care Medicine, 14(6), 535-8.