AN EVALUATION OF METABOLIC FUEL UTILIZATION AT DIFFERING LOW AND MODERATE EXERCISE INTENSITIES

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Bachelor of Science in Education

Oklahoma State University

Stillwater, Oklahoma

1988

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1993

OKLAHOMA STATE UNIVERSITY

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Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to thank the members of my committee, Dr. Steve Edwards, Dr. Bert Jacobson, and chairman Dr. Frank Kulling, for their guidance and support, and in particular Dr. Kulling, for this was his idea from the beginning. I would like to thank the OSU Wellness Center for the generous use of their facility and equipment.

A very special thanks is extended to the staff of the OSU Wellness Center Laboratory. What drudgery this could have been without their soaring spirits!

I would also like to thank my friends from Camp Ozark, who always encouraged, pushed, and prayed for me to finish this investigation.

Finally, this investigation is dedicated to my family, for without their support and love nothing I have ever done could have been possible.

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CHAPTER I

INTRODUCTION

The health benefits of exercise are ordinarily accepted without dispute. Regular exercise has been shown repeatedly to increase functional capacity (FC), to possibly lengthen life, and to generally improve the quality of living (Goldfine, Ward, Taylor Carlucci, & Rippe, 1991).

Traditionally, the emphasis of exercise has focused upon the improvement of maximal FC. This is usually expressed in terms of $\dot{V}O_{2max}$, which is the maximal amount of oxygen a subject is able to consume and utilize for the production of energy, per unit time. The reasoning for such a focus is that a higher $\dot{V}O_{2max}$ increases capacity for leisure-time activities, increases the amount of physical reserve available to perform tasks of daily living, and produces the ability to perform a given workload with less effort (Nieman, 1990). In order to increase $\dot{V}O_{2max}$, exercise is generally prescribed at a relatively high percentage of the current $\dot{V}O_{2max}$, normally 60% to 80%, although for some exercise-limited populations, intensities as low as 40% of maximum work capacity are also recommended (American College of Sports Medicine [ACSM], 1991).

Emphasizing $\dot{V}O_{2max}$ above other components of physical fitness may be unwarranted in specific populations. Studies have suggested that low-intensity exercise may benefit health and promote leanness (Simons-Morton, 1988). Additionally, exercise intensities as low as 42% of FC ($\dot{V}O_{2max}$) can promote cardiorespiratory fitness (Gaesser, 1984; Gossard, 1986), even though gains are minimal. Lower intensity exercise also appears to be more appealing for most Americans, thus promoting better long-term compliance with an exercise regime (Nieman, 1990). Additionally, one of the basic principles of exercise physiology is that lower intensity exercise utilizes a higher percentage of fat than carbohydrate, the two basic fuels used by the exercising muscles (Astrand, 1986). This property of low-intensity exercise will be the focus of this study.

By collecting and analyzing gases expired at the mouth, it is possible to derive the measurement of the respiratory exchange ratio (RER or R). This value is the ratio of the rate of carbon dioxide production to oxygen consumption (CO_2/O_2). R changes as the relative contribution of fat and carbohydrate to the total energy supply changes (Wasserman, Hansen, Sue, & Whipp, 1987). At a high-intensity workload and as R begins to approach or exceed 1.00, carbohydrate is the predominant fuel substrate being used. Conversely, at low intensities of exercise and at rest, R falls to as low as 0.70, which reflects the predominant usage of fat as the fuel for energy (Lusk, 1928).

Tables have been developed which associate any R value with the number of kilocalories (kcal) expended per liter of O_2 consumed (see Table 1, page 32) (Lusk, 1928; McArdle, Katch, & Katch, 1981). These tables also equate a given R value with the percentage of total calories provided by either fat or carbohydrate. By using these tables, it is possible to determine the amount of fat and carbohydrate being consumed per minute at any exercise intensity (Lusk, 1928; McArdle, Katch, & Katch, 1981). The remaining information necessary to collect in order to determine fuel usage, such as $\dot{V}O_2$ and R, can easily be determined by the use of modern laboratory equipment.

Justification and Goals

Among all Americans, only about 28% are considered to be physically active (Schoenborn, 1985). This percentage drops even further if a minimum recommended exercise level of 60% of FC, conducted three times a week for 20 minutes, is considered (Stephens, Jacobs, & White, 1985). Associated with the lack of exercise is the accumulation of excess body fat. Americans are among the fattest people in the world, with a greater percentage of overfat people than either Canada or Britain (Millar, 1987). This excess accumulation of body fat by Americans is one of the more critical medical and public health problems of our time (Pacy, 1986). There are at least seven major health problems associated with excess body fat: (a) a psychological burden, (b) increased blood pressure, (c) increased levels of cholesterol and other blood lipids, (d) increased risk of diabetes, (e) increased risk of cancer, (f) increased risk of an early death, and (g) increased risk of heart disease (National Institutes of Health, 1985). Therefore, the reduction of body fat should be an important consideration when recommending exercise to those people who have a level of body fat above what is desirable.

Based on the health risks associated with excess body fat, it would seem reasonable to postulate that the exercise intensity which emphasizes the oxidation of fat over carbohydrate would be the intensity of choice for people who have such an excess. This is possibly an intensity lower than what is normally prescribed for a healthy population (Kulling, Atkins, & Jacobson, 1992). Therefore, comparisons of metabolic fuel usage at differing low and moderate exercise intensities may be warranted in order to directly evaluate the effects of low- and moderate-intensity exercise upon fuel substrate utilization.

There is some doubt about whether or not low-intensity exercise is beneficial in terms of weight loss or improvement of body composition (Gatorade Sports Science Exchange Roundtable [GSSER], 1992). Surprisingly, there are no published studies which have examined the effects of differing low-intensity exercise levels upon fat and carbohydrate usage expressed in terms of kilocalories per minute. Therefore, the problem of this study was to simulate three differing exercise intensities corresponding to: (a) the minimal intensity prescribed by the ACSM to attain and maintain cardiorespiratory fitness; (b) the intensity which preliminary research by the author has indicated may maximize fat oxidation (Kulling, Atkins, & Jacobson, 1992); and (c) a very low intensity analogous to walking. Respectively, these intensities were 60%, 45%, and 30% of FC (or $\dot{V}O_{2max}$). Parameters selected for study at each intensity were total caloric expenditure per minute (TCAL), fat caloric expenditure per minute (FCAL), carbohydrate caloric expenditure per minute (CCAL), heart rate (HR), $\dot{V}O_2$, R, and %FC.

Statement of the Problem

This study will simulate exercise intensities corresponding to 30%, 45%, and 60% of FC in order to collect and examine possible differences in TCAL, FCAL, CCAL, HR, $\dot{V}O_2$, R, and %FC.

Hypotheses

The hypotheses for this study is as follows: There will be no significant difference in TCAL, FCAL, CCAL, HR, $\dot{V}O_2$, R, and %FC at 30%, 45%, and 60% of FC.

Extent of the Study

Limitations

1. No attempt was made to randomly select study participants.
2. Only a small number of participants were studied.
3. No attempt was made to verify and account for the effect of the subjects' extracurricular activities during the testing period.
4. No attempt was made to verify and account for the effects of the dietary intervention program during the testing period.
5. No attempt was made to measure energy expenditure post-exercise.

Delimitations

1. The six subjects were volunteers drawn from the Oklahoma State University Wellness Center Fitness Center enrollment.
2. The subjects were delimited to females between the ages of 20 and 25 years old, and whose body fat percentage fell between 20% and 25%.
3. Subjects were delimited to those whose YMCA step-test scores were between the categories of "Good" and "Above Average" (Golding, Myers, & Sinning, 1989).
4. Dietary intervention occurred prior to the initial GXT in order to homogenize diet, and thus resting R values, among the subjects.

5. Each subject underwent a 10 hour fast prior to testing.

Assumptions

1. Adherence to test guidelines involving diet and fasting was assumed.
2. The oxidation of fat can be represented by the oxidation of palmitic acid, based on the observation that palmitate turnover is representative of about 75% of the total free fatty acid in the plasma (Havel, Carlson, Ekelund, & Holmgren, 1964).
3. The oxidation of protein as an energy substrate was insignificant and not relevant to this study (Lamb, 1978).

Definition of Terms

Conceptual

Acetyl coenzyme A (Acetyl CoA). A molecule which is the common product of fat and carbohydrate oxidation. Acetyl CoA functions to begin the citric acid cycle by assisting in the formation of the first intermediate (Marieb, 1989).

Adenosine triphosphate (ATP). An organic molecule which functions as the unit of energy currency by releasing or storing chemical energy (Marieb, 1989).

Adipose tissue. A conglomeration of cells comprised mostly of triglycerides. Adipose tissue serves as the main storage site for fats (Marieb, 1989).

Aerobic metabolism. Metabolism carried out in the presence of oxygen (Marieb, 1989).

Albumin. An abundant plasma protein which, among other things, acts as a transport molecule for free fatty acids (Davis, 1973).

Anaerobic metabolism. Metabolism carried out in the absence of sufficient oxygen (Marieb, 1989).

Anaerobic Threshold (AT). The highest point of oxygen consumption that is not associated with a sustained increase in blood lactate levels (Wasserman, et al., 1987). Respiratory values, such as R, obtained at or above AT are influenced by excess CO_2 produced by the mechanisms of lactate buffering.

Beta-oxidation. A series of reactions which results in a free fatty acid being converted into acetyl CoA (Stryer, 1988).

Bicarbonate. An ion involved in the buffering of blood acids, particularly lactic acid. Replacement of bicarbonate requires CO_2, and results in a lowering of the R value (Marieb, 1989; Wasserman et al., 1987).

Carbohydrate (CHO). A class of chemical compounds consisting of carbon, oxygen, and hydrogen. Often abbreviated as CHO, common forms are starches, sugars, and dietary fibers. Carbohydrates, as a source of energy, usually supply about 4 kcal per gram (Gollnick & Saltin, 1988).

Citric acid cycle. The chemical pathway by which energy, in the form of ATP, is derived from acetyl CoA (Stryer, 1988). This is an aerobic process.

Disaccharide. A molecule consisting of two sugar residues, such as sucrose (glucose and fructose) (Stryer, 1988).

Exercise intensity. A measure of the relative stress placed on a subjects physiological system. This relative measure is usually assigned as a percentage of some maximal function, usually heart rate or $\dot{V}O_2$ (Katch et al., 1981).

Fat. A class of chemical compounds with the general structure of $CH_3(CH_2)_nCOO^-$ (Stryer, 1988). Fats can be either saturated (no double bonds within their structure), or unsaturated (one or more double bonds within their structure). In this study, the general assumption will be made that the oxidation of fat can be represented by the oxidation of palmitic acid ($CH_3[CH_2]_{14}COO^-$) (Gollnick & Saltin, 1988). One gram of fat yields about 9 kcal of energy (Stryer, 1988).

Free fatty acids (FFA). Organic molecules comprised of a long carbon chain and a terminal carboxylate group. Three FFA combine with glycerol to form a triglyceride (Stryer, 1988).

Fructose. A ketose sugar having the formula $C_6H_{12}O_6$, and which is found predominantly in the form of a furanose ring (Stryer, 1988).

Functional capacity. The highest rate of oxygen consumption of which a person is capable. Usually expressed in milliliters of oxygen per kilogram of body weight per minute (ml/kg/min) (Nieman, 1990).

Glucose. An aldose sugar having the formula $C_6H_{12}O_6$, and which is found predominantly in the form of a pyranose ring (Stryer, 1988).

Glycogen. A large, branched polymer of glucose residues. Glycogen is the storage form for glucose (Stryer, 1988).

Kilocalorie. 1 kilocalorie (kcal) is equal to 1000 calories. One calorie is the amount of energy needed to raise the temperature of 1 gram of water 1 degree Celsius, at sea level. Energy exchanges associated with biochemical reactions, such as the oxidation of fat, are usually reported in kilocalories (Marieb, 1989).

Lactate. The end product of the anaerobic metabolism of glucose (Nieman, 1990). Lactate accumulation can halt muscular activity by lowering the cell pH below its' enzymes functional range (deVries, 1986).

Lipolysis. The hydrolysis of a triglyceride into glycerol and three fatty acids (Gollnick & Saltin, 1988).

Maximal exercise test. An exercise test limited by the inability of the subject to perform increasing intensities of physical work (Wasserman et al., 1987).

MET. A measure of energy output equal to the basal metabolic rate of a resting subject. Assumed to equal an oxygen uptake of 3.5 ml/kg/min (1 MET = 3.5 ml/kg/min) (Nieman, 1990).

<u>Monosaccharide</u>. A single sugar molecule, such as glucose or fructose (Stryer, 1988).

<u>Oxidation</u>. The energy-yielding chemical process by which a substance loses electrons or gains oxygen (Thomas, 1973). Food substrates are repeatedly oxidized, ultimately resulting in the formation of ATP, the form in which energy is used by the body (Marieb, 1989).

<u>Palmitate (Palmitic Acid)</u>. A fatty acid having the general structure $CH_3(CH_2)_{14}COO^-$, and which is considered to be representative of all FFA turnover (Gollnick & Saltin, 1988; Stryer, 1988).

<u>Polysaccharide</u>. A molecule consisting of many sugar residues linked together, such as starch or glycogen (Stryer, 1988).

<u>Respiratory Exchange Ratio (RER or R)</u>. The ratio of the rate of carbon dioxide production to oxygen consumption as measured at the mouth (Wasserman et al., 1987). During steady-state, this ratio reflects the exchange of these gases by the working tissues and is representative of substrate utilization.

<u>Respiratory Quotient (RQ)</u>. The ratio of the rate of carbon dioxide production and oxygen consumption within the tissue (Wasserman et al., 1987). RQ may or may not be different than the R value.

Starch. A polysaccharide found in plants that is similar to glycogen, except that it is either unbranched (amylose), or has a lower degree of branching (amylopectin) (Stryer, 1988). Starch is the main supply of dietary carbohydrate (Saltin et al., 1988).

Steady-state. A characteristic of a physiological system in which its functional demands are being met such that its output per unit time becomes constant (Wasserman et al., 1987).

Substrate. A substance which is acted upon by enzymes in order to produce different molecules, including energy in the form of ATP (Stryer, 1988). Those substrates that provide energy are typically carbohydrates, fats, and proteins.

Sucrose. A disaccharide comprised of a glucose residue and a fructose residue (Stryer, 1988).

Triacylglycerol. Synonymous with triglyceride.

Triglyceride. Uncharged esters of glycerol which contain three fatty acid residues (Stryer, 1988). Triglycerides are the storage form for FFA.

$\dot{V}O_{2max}$. The maximal volume of oxygen consumed per unit time. This can be considered to be an expression of functional capacity (Nieman, 1990).

Functional

GXT. A graded exercise test performed on a treadmill.

Metabolic (met) cart. A laboratory device which analyzes expired gases through the use of a mixing chamber and O_2 and CO_2 sensors. The met-cart is programmable so as to supply the desired data parameters. The met-cart used will be a Quinton Q-Plex I.

CHAPTER II

REVIEW OF LITERATURE

In order to understand the relationship between exercise intensity and metabolic fuel usage, it is useful to have an understanding of the nature of fats and carbohydrates in general, and the means by which they are used as metabolic fuels.

Fats and Fat Metabolism

Fats (or lipids) can be described in broad terms as a class of biologically important molecules which are insoluble in water and soluble in organic solvents. The fats which are most involved in the production of metabolic energy are the free fatty acids (FFA), and their storage form, triglycerides (TG) (Gollnick & Saltin, 1988).

Triglycerides

A TG consists of a glycerol molecule combined with three FFA molecules (Stryer, 1988). Triglycerides, or triacylglycerols, are highly concentrated stores of metabolic energy. Approximately 9 kcal per gram are produced by the complete oxidation of the FFA component of TG, which is more than twice that of carbohydrate and protein (Stryer, 1988; Williams, 1985). The major site of TG accumulation is the adipose tissue (Williams, 1985). From there, under the influence of hormones, FFA are liberated from TG by the process of lipolysis (hydrolysis of the TG), pass into the blood circulation, and are bound to albumin for transport to the working muscle (Gollnick & Saltin, 1988). It is important to note that muscle has little stored FFA, and the use of fat as a metabolic fuel is dependant upon this mobilization of FFA from the TG stores.

Fatty Acids

Fatty acids are a class of compounds that contain a long hydrocarbon chain and a terminal carboxylate (COO^-) group. Fatty acids vary in hydrocarbon chain length, with most biologically important FFA having between 14 and 24 carbon atoms (Stryer, 1988). Also, FFA have a variety of structures with some being saturated, that is, having no double bonds within the hydrocarbon chain, while others are unsaturated, having one or more double bonds (Gollnick & Saltin, 1988). Palmitate, or palmitic acid, is a fatty acid with the chemical composition of $CH_3(CH_2)_{14}COO^-$, and is representative of about 75% of the total FFA in blood plasma (Gollnick & Saltin, 1988; Havel et al., 1964). Therefore, the turnover of FFA into metabolic energy can assumed to be represented by the turnover of palmitic acid (Havel et al., 1964).

Once the FFA-albumin complex reaches the working muscle cell, the FFA is liberated and taken up by the cell. The FFA then undergoes a process known as beta-oxidation, which is the progressive cleaving (oxidation) of the molecules' carbon backbone (Gollnick & Saltin, 1988). The result of beta-oxidation is the formation of acetyl coenzyme A (acetyl CoA), which then enters the citric acid cycle, the adenosine triphosphate (ATP) producing pathway. The complete oxidation of one palmitic acid molecule results in 129 molecules of ATP (Stryer, 1988).

Carbohydrates and Carbohydrate Metabolism

Carbohydrate (CHO) is a class of chemical compounds consisting of repeated units of CH_2O (Saltin & Gollnick, 1988; Stryer, 1988). Some typical types of CHO are monosaccharides, disaccharides, and starch. Glucose and fructose, which are the two most important monosaccharides, both have the general chemical structure $C_6H_{12}O_6$. The linking of glucose with fructose, through a condensation reaction, results in sucrose, a disaccharide, which is the greatest dietary source of glucose and fructose (Saltin & Gollnick, 1988). Glucose, because of its high rate of absorption, is considered to be the most important monosaccharide (Stryer, 1988).

The storage form of CHO is glycogen (Saltin & Gollnick, 1988). Glycogen is a large, branched polymer of glucose, and is found in various storage pools (Saltin & Gollnick, 1988; Stryer, 1988). The overall amount of glucose storage in the form of glycogen is rather small, particularly when compared with the amount of FFA storage in adipose tissue (Gollnick & Saltin, 1988). The glycogen found in the liver is normally used exclusively for body glucose homeostasis, and is not readily mobilized for use by working muscles (deVries, 1986; Saltin & Gollnick, 1988). Most of the glycogen used to supply the body with glucose for muscular exercise is found in the muscle itself (Gaesser & Brooks, 1980).

Mobilized glucose molecules are, through a series of reactions, converted into pyruvate, which is then converted into acetyl CoA. Acetyl CoA then enters the citric acid cycle, yielding 36 molecules of ATP for each molecule of glucose (Stryer, 1988; Wasserman et al., 1987).

As previously indicated, CHO provides less energy per gram than does FFA. Indeed, one gram of CHO provides approximately 4 kcal of energy.

Respiratory Exchange Ratio

The respiratory exchange ratio, abbreviated RER or R, is defined as the ratio of the rate of CO_2 production to O_2 consumption as measured at the mouth (Wasserman et al., 1987). A true metabolic respiratory quotient (RQ), however, is defined as the ratio of the rate of CO_2 production to O_2 consumption as a function of cellular respiration (West, 1991). R accurately reflects RQ only during steady-state conditions (Wasserman et al., 1987). R can either exceed or fall below RQ, depending on various metabolic conditions.

The measurement of R is a reflection of the mixture of fuels being oxidized for energy. Complete oxidation of pure FFA yields an R value of 0.70, as illustrated by equations (1) and (2).

$$C_{16}H_{32}O_2 + 23\ O_2 \text{ --> } 16\ CO_2 + 16\ H_2O + 36\ ATP \quad (1)$$

$$R = CO_2/O_2 = 16/23 = 0.70 \quad (2)$$

It is impossible for RQ to fall below 0.70. However, R may fall below 0.70 if CO_2 is retained during the replacement of bicarbonate stores that were depleted during lactate buffering (Lamb, 1978).

Likewise, the oxidation of only CHO results in an R value of 1.00. This can be represented by the equations (3) and (4).

$$C_6H_{12}O_6 + 6\ O_2 \text{ --> } 6\ CO_2 + 6\ H_2O \quad (3)$$

$$R = CO_2/O_2 = 6/6 = 1.00 \quad (4)$$

R may exceed 1.00 during heavy exercise due to excess CO_2 being ventilated as a result of the lactate buffering system. However, RQ may not (Lamb, 1978).

At rest, R is mostly a reflection of diet (Christensen & Hansen, 1939). A typical American diet results in an R value of approximately 0.75 to 0.80 (Lusk, 1928; Wasserman et al., 1987). During exercise, R is a reflection of the mixture of the substrates being used for energy. As exercise intensity increases, R also rises, reaching a steady-state for a given exercise intensity in two to three minutes (Benedict & Cathcart, 1913; Wasserman et al., 1987). At near-maximal exercise levels, R approaches or exceeds 1.00, reflecting the exclusive use of CHO as the metabolic fuel (Lusk, 1928).

R values can also be equated to the amount of energy, in kcal, obtained per liter of oxygen consumed (Lusk, 1928). This relationship between $\dot{V}O_2$ (in liters) and the percentage of carbohydrate and fat utilized (based on the R value), is demonstrated graphically in Figure 1.

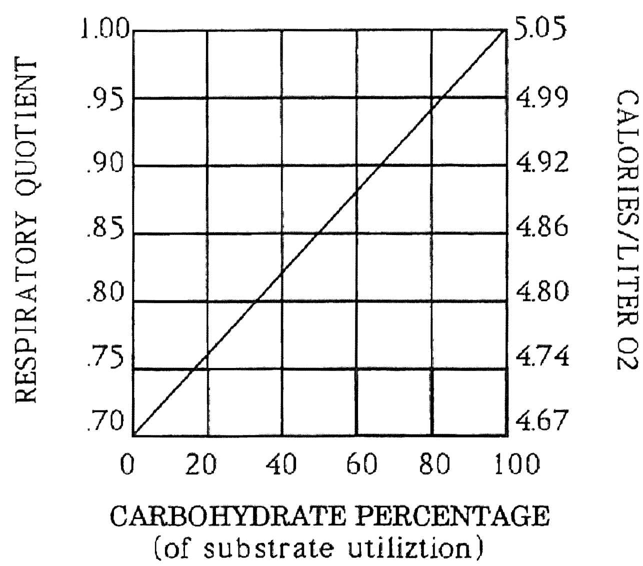

Figure 1. Percentage of carbohydrate substrate utilization based on R measurements. Kcal of energy obtained per liter of oxygen consumed for each combination is given on the right ordinate (Adapted from Wasserman et al., 1987, p. 7).

Another aspect of R that is crucial to this study is that the measurement obtained is a nonprotein R value. The oxidation of protein results in an R value of approximately 0.80 (deVries, 1986). However, the amount of protein that contributes to metabolic energy during short duration exercise (less than 30 minutes) is insignificant and can be ignored (Lamb, 1978).

Previous Studies

There appear to be no studies which directly compare the differences in substrate utilization as a result of differing low- and moderate-intensity exercise bouts, nor any studies which attempt to determine the exercise intensity which would elicit the greatest amount of fat oxidation. Ballor, McCarthy, and Wilterdink (1990) conducted a study similar in concept in which they compared the changes in body mass composition after eight-week exercise programs prescribed at high and low exercise intensities. Exercise bouts at each intensity were held constant with regard to total caloric expenditure, and all subjects were under dietary caloric restriction. However, this study somewhat arbitrarily assigned the low-intensity exercise sessions as 42.5% of $\dot{V}O_{2max}$, half of the intensity prescribed for the high-intensity group. There appeared to be no effort to establish a low-intensity exercise level at which fat consumption was maximized, nor to compare differences in substrate utilization between differing low-level intensities. These are key differences between the Ballor et al. (1990) study and the one conducted here. Additionally, the 1990 study examined the results of high- versus low-intensity exercise over an eight week period. No comparisons were made in regard to single exercise bouts. Study results indicated no significant differences in the make-up of the body mass that was lost as a result of the exercise sessions. Low intensity exercise, which emphasized the consumption of fat over carbohydrate, did not result in significant losses of body fat over high intensity exercise.

In a study by Tremblay et al. (1990), the effect of the intensity of physical activity upon body fatness was examined. No attempt was made to establish an activity intensity level at which fat consumption was maximized, nor to compare differences among low-level intensities. Indeed, this study simply categorized their subjects into four different activity intensity levels based upon predicted MET values for reported activities. The findings in this study were that subcutaneous fat was generally lower in subjects who regularly practiced vigorous physical activities. However, the design of this study was such that it is impossible to make any conclusions about whether or not there is an exercise intensity which would maximize the loss of body fat.

Weltman, Matter, and Stamford (1980) demonstrated that the most effective means of losing body fat was to combine a caloric restriction with exercise of at least moderate intensity. Exercise alone was shown to be relatively ineffective in lowering percentage body fat. Again, however, the moderate exercise used in this study was arbitrarily assigned. No conclusions can be drawn about the effects that differing low-level exercise intensities might have upon substrate utilization.

Recently, the notion of low-intensity exercise promoting leanness has come under criticism from experts in the field of exercise physiology. Dr. William McArdle states that "by applying this argument (of low-intensity exercise) I think you can miss the point that the whole approach to weight loss is predicated on creating a prolonged caloric imbalance. The substrate being burned to create this imbalance is probably secondary" (GSSER, 1992, p. 2). In the same source, Dr. Jack Wilmore states that "the concept of 'fat burning' vs. 'carbohydrate-burning' exercises to promote weight loss is a common myth perpetrated by aerobics instructors, among other fitness professionals." Additionally, he states that calculations have been done "which indicate that although you may be burning a larger percentage of fat with low-intensity exercise, the total grams of fat burned is actually greater with higher intensity exercise, because the total energy output is higher during intense activity" (GSSER, 1992, p. 2).

Stanforth and Stanforth (1992) make similar arguments. They emphasize that although low-intensity exercise does derive a larger percentage of total calories from fat, the total number of calories expended is too small in comparison to high-intensity exercise to make this percentage difference translate into increased fat oxidation. Instead, the authors argue that "the amount of weight loss is dependent upon the total number of calories expended rather than the intensity of exercise or even the type of calories expended" (Stanforth & Stanforth, 1992, p. 7).

Because of the equivocal nature of the literature and the questions which surround this issue, there is a need for investigations which directly compare substrate utilization at differing low and moderate exercise intensities.

CHAPTER III

METHODS AND PROCEDURES

This study investigated physiological responses to differing low and moderate exercise intensities in terms of FCAL, CCAL, TCAL, HR, $\dot{V}O_2$, R, and %FC. The methods and procedures were submitted to and approved by the Oklahoma State University (OSU) Institutional Review Board (IRB).

Selection of Subjects

The six female subjects were solicited as study volunteers from the OSU Wellness Center Fitness Center enrollment. Prior to acceptance for participation in the study, it was determined that each subject met the criteria for acceptance. The criteria included (a) an age between 20 and 25 years, (b) 20% to 25% body fat as determined by skinfold measurements (Jackson & Pollock, 1985), and (c) a score which fell between "good" and "above average" on the YMCA bench step-test (Golding et al., 1989). Upon acceptance into the study, each subject was given an OSU IRB-approved informed consent document which outlined the procedures, risks, and benefits of the study (see appendix A). The subjects were required to read and sign the consent form prior to any testing. The form was thoroughly explained to the subjects by the investigator and questions were answered to the satisfaction of each of the subjects.

Subjects were also instructed that normal exercise routines should not be altered during the testing period.

Dietary Intervention Prior to Testing

Dietary intervention began four days prior to the initial treadmill test, and was done in an effort to homogenize resting R values. Approximately one week prior to their initial treadmill test, each subject reported to the investigator in order to receive oral and written instructions regarding this intervention. A Registered Dietician (R.D.) was consulted by the investigator regarding specifics of the intervention. The subjects were instructed not to exceed a daily 1800 kcal intake, and to maintain an approximate caloric distribution of 20% protein, 55% CHO, and 25% fat. This dietary plan was based on the notion of food exchanges, which equate serving sizes with approximate kcal amounts and nutrient distribution (E. Lohrman, personal communication, October, 1992). Each subject was given a packet which included written information regarding serving sizes and exchange values, as well as a form for maintaining a dietary diary. This packet was not returned to the investigator, but was meant to serve as a guide for the subjects. No attempt other than verbal confirmation was made to determine actual compliance with the intervention.

Initial Treadmill Test

Each subject reported to the laboratory having fasted for at least ten hours in order to assure a post-absorptive state (Björkman & Wahren, 1988). Each subject was required to read and sign an IRB-approved laboratory informed consent document regarding the exercise test (see Appendix A), and was was also given the opportunity to ask questions about the test.

Once informed consent was obtained, preliminary physical measurements were obtained and recorded. These measurements included height, weight, grip strength, flexibility, forced vital capacity (FVC), and body fat percentage. These were obtained in accordance with laboratory procedure.

The subjects were then prepared for monitoring during the test. Monitoring systems included an automated treadmill controller and twelve-lead electrocardiograph (ECG) and an automated blood pressure (b.p.) cuff system. A calibrated, programmable met-cart was used for analyzing expired gases via a one-way breathing valve (see Appendix C for a listing of instruments). Also at this time, hand signals were established as a means of communicating during the test.

Once the monitoring equipment was in place, a supine resting ECG and b.p. reading were recorded in accordance with laboratory procedures. The exercise test began after obtaining these readings.

The test protocol began with a five minute warm-up during which the subject became accustomed to the treadmill and reached a steady-state of exercise (see functional definition). After the warm-up, five two-minute stages followed, and then subsequent one-minute stages until exhaustion. Each stage increase was between 0.8 and 1.4 METS (see appendix C). Met-cart data was collected every 20 seconds, and a computer printout was generated concurrently (see Appendix B for a sample printout). The subjects ECG was constantly monitored visually, and b.p. readings were obtained every three minutes. The met-cart displayed several test parameters real-time, including R and $\dot{V}O_2$.

Upon indication by the subject that maximal work capacity had been reached, the test was terminated and the subject began a cool-down of at least five minutes in length. The met-cart breathing valve was removed from the subject during cool-down because post-exercise data was not needed, and because of the discomfort associated with the mouthpiece. A post-test report was generated which displayed, among other things, maximum FC, HR, and R.

Second Treadmill Test

The second treadmill test was designed to elicit steady-state physiological responses which corresponded to 30%, 45%, and 60% of FC as determined by the initial treadmill test. Each test was individualized based on FC, and treadmill test speed and grade were calculated by using an available metabolic calculation (ACSM, 1991, p. 296).

Determination of treadmill speed and grade

The treadmill protocol for the second test consisted of three separate stages, each of which was at least six minutes long. The first stage was conducted at 30%, the second at 45%, and the third at 60% of FC. The speed and grade necessary to achieve the desired intensity was calculated by using the respective percentage (in decimal form) of the subjects $\dot{V}O_{2max}$ as determined by the initial treadmill test, and the ACSM formula for oxygen consumption (ACSM, 1991, p. 296). For convenience, a speed of 3.0 mph was used, and only the different grades had to be calculated. For one subject, however, a speed of 2.9 mph was used because this speed yielded results which more closely approximated the desired percentages, given that the treadmill was adjustable only in one-half degree intervals. The ACSM formula as used is shown as equation 5:

$$G = \frac{(P \times \dot{V}O_{2max}) - (\text{meters/min} \times 0.1) - (3.5)}{(\text{meters/min} \times 1.8)} \qquad (5)$$

G = grade percentage in decimal form

P = desired percentage of functional capacity

$\dot{V}O_{2max}$ is expressed in milliliters per kilogram per minute (ml/kg/min). The value 3.5 represents resting oxygen consumption (one MET), and is also expressed in ml/kg/min. Meters/min is the metric equivalent of mph and is determined by the conversion factor of 1 mph = 26.8 meters/min (a speed of 3.0 mph equals 80.4 meters/min, and 2.9 mph equal 77.7 meters/min). The values 1.8 and 0.1 are both constants, and are expressed in units of (ml/kg/min)/(meters/min). All grade percentages were rounded to the nearest one-half of a degree.

Administration of the test

Even though each subject was encouraged to complete the low- and moderate-intensity treadmill test within one week of the initial test, the average time between tests was almost four weeks. Nevertheless, all subjects reported that exercise and dietary habits remained constant during this time, and therefore, even a four-week delay was not estimated to be detrimental.

Each subject was again instructed to begin dietary intervention four days before the test, using the same guidelines as for the initial test, and to use their previous dietary diary as a guide. Likewise, only verbal confirmation was obtained in order to assure compliance with the intervention.

Other than the actual treadmill protocol and the physical measurements taken before the test, the methods used for the low- and moderate-intensity treadmill test were identical to those which were used for the determination of FC. An informed consent document was presented, explained and signed by each subject before the test, and weight and body-fat percentage was determined. The monitoring equipment was then affixed, and resting ECG and b.p. readings were obtained.

The treadmill protocol consisted of three separate stages, each of which was at least six minutes long. The first stage was conducted at 30% of FC, the second at 45% of FC, and the third at 60% of FC. The desired speed and grade were calculated as described previously.

This test protocol did not include a warm-up. Each subject began her test at the speed and grade which was calculated to elicit an intensity response equal to 30% of functional capacity, as determined by the initial GXT. In order to advance the subject from one stage to the next, two criteria had to be met: (a) the subject must have completed at least six minutes of the present stage, and (b) the subject must have presented at least three minutes of physiological data which would indicate a steady-state of exercise. A steady-state of exercise was determined by the R value, which, in order to be considered in steady-state response, had to vary by no more than $\pm$ 0.05 within any three-minute interval (nine readings of the met-cart).

After the completion of the last stage of the test, the subject underwent a cool-down as before. Completion of the low- and moderate-intensity treadmill test completed the data-generating portion of the study.

Determination of Dependant Variables

The data generated during the second test was used to examine FCAL, CCAL, TCAL, HR, $\dot{V}O_2$, and R for the differing levels of low- and moderate-intensity exercise. Also examined was the actual percentage of functional capacity that each treadmill stage actually represented.

By using R and $\dot{V}O_2$ in conjunction with the table published by McArdle et al. (1981) (see Table 1), FCAL, CCAL, and TCAL were determined using the following steps:

1. Average R and $\dot{V}O_2$ was determined for the last three minutes (nine readings) of each stage, as marked in Appendix B, page 60-61.

2. By using Table 1, the caloric equivalent for each liter of O_2 consumed ($\dot{V}O_2$), based upon R, was determined.

3. This number was multiplied by $\dot{V}O_2$ (L/min). The result was TCAL.

4. TCAL was multiplied by the respective percentages of fat and CHO contribution as dictated by R. The results were FCAL and CCAL.

HR, $\dot{V}O_2$, R, and actual %FC were also determined by using an average of the last three minutes of each stage. Actual percentage of functional capacity was determined by using the average value for $\dot{V}O_2$ (L/min) during the same time period, and dividing it by $\dot{V}O_{2max}$ (L/min).

TABLE 1

THERMAL EQUIVILANT OF OXYGEN FOR NONPROTEIN R VALUES, INCLUDING PERCENT KCAL DERIVED FROM CHO AND FAT

Nonprotein R	kcal per liter O2 consumed	Percentage kcal derived from CHO	Percentage kcal derived from Fat
0.70	4.686	0.00	100
0.71	4.690	1.10	98.9
0.72	4.702	4.76	95.2
0.73	4.714	8.40	91.6
0.74	4.727	12.0	88.0
0.75	4.739	15.6	84.4
0.76	4.751	19.2	80.8
0.77	4.764	22.8	77.2
0.78	4.776	26.3	73.7
0.79	4.788	29.9	70.1
0.80	4.801	33.4	66.6
0.81	4.813	36.9	63.1
0.82	4.825	40.3	59.7
0.83	4.838	43.8	56.2
0.84	4.850	47.2	52.8
0.85	4.862	50.7	49.3
0.86	4.875	54.1	45.9
0.87	4.887	57.5	42.5
0.88	4.889	60.8	39.2
0.89	4.911	64.2	35.8
0.90	4.924	67.5	32.5
0.91	4.936	70.8	29.2
0.92	4.948	74.1	25.9
0.93	4.961	77.4	22.6
0.94	4.973	80.7	19.3
0.95	4.985	84.0	16.0
0.96	4.998	87.2	12.8
0.97	5.010	90.4	9.58
0.98	5.022	93.6	6.37
0.99	5.035	96.8	3.18
1.00	5.047	100	0.00

From McArdle, W. D., Katch, F. I., & Katch, V. L. (1981). Exercise physiology - energy, nutrition, and human performance. Philadelphia: Lea and Febiger. Pg. 101.

Analysis of Data

Statistical analysis involved determining among-group differences with an alpha level of .01 ($p < .01$) using a one-way repeated measures analysis of variance (ANOVA) for each dependent variable grouped by exercise intensity. The dependant variables were TCAL, FCAL, CCAL, HR, R, $\dot{V}O_2$, and %FC. Newman-Kuels test was used to determine significant post hoc differences between groups ($p < .01$).

CHAPTER IV

RESULTS AND DISCUSSION

The problem of this study was to determine differences in FCAL, CCAL, TCAL, HR, $\dot{V}O_2$, and R at three different low and moderate exercise intensities. Additionally, this study identified the actual percentage of functional capacity at which the exercise was performed during the second test as opposed to the percentage predicted by the ACSM oxygen consumption formula (ACSM, 1991, p. 296).

Results

Study Subjects

Six subjects were used in the investigation, all of whom met the criteria established for acceptance. Table 2 shows selected subject descriptive information, including age, body fat percentage, step-test score, weight, and $\dot{V}O_{2max}$ as determined by the initial treadmill test.

Results of Low- and Moderate-Intensity Treadmill Test

The subject-by-subject results for each of the three stages of the low- and moderate-intensity treadmill test are given in Table 3.

TABLE 2

SELECTED SUBJECT VARIABLES

			Variable		
Subject No.	Age	Body Fat %	Y.M.C.A. Fitness Cat.	Weight (kg)	$\dot{V}O2max$ ml/kg/min
1	22	25.5	Above Average	73.2	41.6
2	21	24.7	Above Average	59.5	39.9
3	22	19.3	Good	50.9	40.2
4	21	24.5	Average	70.5	40.2
5	22	22.5	Average	53.2	39.4
6	20	24.7	Good	60.9	37.4
mean	21.3	23.5	____	61.4	39.8
s.d.	±0.82	±2.3		±8.98	±1.38

TABLE 3

SUBJECT-BY-SUBJECT RESULTS OF THE
SECOND TREADMILL TEST

30% FC

Subject No.	Actual %F.C.	Heart Rate	R	$\dot{V}O2$ (L/min)	Fat kcal/min	CHO kcal/min	Total kcal/min
1	30	93	0.74	0.92	3.83	0.52	4.35
2	30	113	0.82	0.69	1.99	1.34	3.33
3	33	97	0.75	0.68	2.72	0.50	3.22
4	26	99	0.73	0.73	3.15	0.29	3.44
5	33	107	0.75	0.71	2.84	0.53	3.37
6	28	96	0.82	0.64	1.84	1.24	3.09
mean	30.00	100.83	0.77	0.73	2.73	0.74	3.47
s.d.	±2.76	±7.60	±0.04	±0.1	±0.74	±0.44	±0.45

45% FC

Subject No.	Actual %F.C.	Heart Rate	R	$\dot{V}O2$ (L/min)	Fat kcal/min	CHO kcal/min	Total kcal/min
1	43	112	0.79	1.3	4.36	1.86	6.22
2	40	133	0.82	0.93	2.68	1.81	4.49
3	42	121	0.81	0.86	2.61	1.21	3.82
4	37	122	0.82	1.04	3.00	2.02	5.02
5	44	123	0.82	0.95	2.74	1.85	4.58
6	38	112	0.88	0.86	1.65	2.56	4.21
mean	40.67	120.50	0.82	0.99	2.84	1.88	4.72
s.d.	±2.80	±7.87	±0.03	±0.17	±0.52	±0.43	±0.84

60% FC

Subject No.	Actual %F.C.	Heart Rate	R	$\dot{V}O2$ (L/min)	Fat kcal/min	CHO kcal/min	Total kcal/min
1	56	130	0.84	1.68	4.30	3.85	8.15
2	53	155	0.82	1.22	3.51	2.37	5.89
3	58	141	0.86	1.19	2.66	3.14	5.80
4	51	148	0.84	1.45	3.71	3.32	7.03
5	60	149	0.89	1.28	2.25	4.04	6.29
6	52	130	0.92	1.19	1.53	4.36	5.89
mean	55.00	142.17	0.86	1.34	2.99	3.51	6.51
s.d.	±3.58	±10.42	±0.04	±0.20	±1.03	±0.43	±0.93

The mean and standard deviation (s.d.) for each parameter at each different exercise level is calculated, and it is these means that were tested for significance ($p<.01$).

The test parameter means were tested for significant differences ($p<.01$) among exercise levels by using a one-way repeated measures ANOVA for each parameter. The results of the statistical analysis are shown in Table 4. The Newman-Kuels post hoc test was used to discern differences between values obtained at each exercise level ($p<.01$).

<u>Analysis of Fat Caloric Expenditure.</u> Table 4 shows no significant difference among FCAL obtained during each exercise level ($p>.05$). There was no post hoc treatment.

<u>Analysis of Carbohydrate Caloric Expenditure</u>. Table 4 shows a difference in CCAL among the exercise levels at the .01 level of significance. The post hoc test indicated a difference among all values at the .01 level of significance.

<u>Analysis of Total Caloric Expenditure.</u> Table 4 shows a difference in TCAL among the exercise levels at the .01 level of significance. The post hoc test indicated a difference among all values at the .01 level of significance.

<u>Analysis of Heart Rate.</u> Table 4 shows a difference in HR among the exercise levels at the .01 level of

significance. The post hoc test indicated a difference among all values at the .01 level of significance.

Analysis of $\dot{V}O_2$. Table 4 shows a difference in $\dot{V}O_2$ among the exercise levels at the .01 level of significance. The post hoc test indicated a difference among all values at the .01 level of significance.

Analysis of R Value. Table 4 shows a difference in the R value among the exercise levels at the .01 level of significance. The post hoc test indicated a difference among the R value of the lowest intensity level and both of the other two levels at the .01 level. Post hoc differences between middle and highest intensities was not significant at .01 ($p>.01$), but was significant at .05 ($p<.05$).

Analysis of Actual Percentage of Functional Capacity. Table 4 shows a difference in the actual percent of FC among the exercise levels at the .01 level of significance. The post hoc test indicated a difference among all values at the .01 level of significance.

TABLE 4

RESULTS OF ONE-WAY REPEATED MEASURES
ANOVA BY TEST INTENSITY

Source	SS	df	MS	F	P
%FC					
T	1888.445	2	944.2237	988.23	P < .01*
S	131.777	5	26.3555		
S x T	9.555	10	0.9555		
R value					
T	0.026	2	0.0132	20.663	P < .01*
S	0.013	5	0.0027		
S X T	0.006	10	0.0006		
$\dot{V}O2$ (L/min)					
T	1.111	2	0.5555	183.23	P < .01*
S	0.347	5	0.0693		
S x T	0.030	10	0.0030		
FCAL					
T	0.210	2	0.1048	0.634	P > .05
S	10.247	5	2.0493		
S x T	1.655	10	0.1655		
CCAL					
T	23.386	2	11.6931	49.999	P < .01*
S	2.157	5	0.4313		
S x T	2.339	10	0.2339		
TCAL					
T	28.067	2	14.0333	161.393	P < .01*
S	7.918	5	1.5837		
S x T	0.870	10	0.0870		
HR (bpm)					
S	5129.344	2	2564.6720	291.44	P < .01*
T	1053.156	5	210.6313		
S x T	88.000	10	8.8000		

T = treatment
S = subject

* - indicates significance

An important aspect of this study was to examine the actual percentage of functional capacity that each stage in the second treadmill test represented. The ACSM formula for oxygen consumption was used in order to calculate the speed and grade necessary to achieve the target percentages of 30%, 45%, and 60% (ACSM, 1991). However, as is shown in Table 3, two of the actual percentages ranged from these target percentages appreciably. The mean percentages were, respectively, 30%, 41%, and 55%. Therefore, throughout the remaining discussion, these actual percentages were used to identify the low and moderate intensities of the treadmill exercise.

Accompanying the significant differences in exercise intensities were significant differences in HR, VO_2, and R values. These values would be expected to change significantly in response to exercise intensity increases, and were used mainly as means by which to describe such intensity changes. VO_2 and R values were also used in the calculation of substrate utilization.

The relationship between substrate utilization and exercise intensity is at present only partly understood. It is known that lower intensities of work utilize a higher percentage of fat compared to carbohydrate. What is unclear is whether or not there is an intensity of work which maximizes the absolute contribution of fat as a metabolic fuel through a combination of R value and total caloric fuel through a combination of R value and total caloric expenditure. Also unclear at the present is whether or not such an intensity would result in an enhancement of body fat loss.

Based on the second treadmill test which simulated exercise performed at 30%, 41%, and 55% of FC, fat expenditure per minute was higher for some subjects at 30% FC versus 55% FC, although the means suggest that fat consumption was highest at 55% FC (see Table 3).

These results should in no way be interpreted to suggest that a regime of low- to moderate-intensity exercise will result in increased body fat loss compared to high-intensity exercise. What is suggested is that at the identified low intensity (30% of FC), fat oxidation per minute was not significantly lower than at a higher intensity (55% FC). Base on this, an exerciser, whose intent and purpose for exercise is primarily the reduction of body fat, may possibly benifit from low-intensity exercise equally as much as they might from a higher intensity level.

Additionally, if total caloric expenditure is kept equal between exercise bouts conducted at low versus high intensities, the bout conducted at a low intensity will utilize significantly more calories from fat. This would mean, however, that the time spent exercising would have to be increased for the low-intensity exercise.

The data from Table 3 may be used as an example in order to illustrate this concept. At the low-intensity stage of 30% FC, Subject No. 5 demonstrates an R value of .75 and a $\dot{V}O_2$ of 0.71 L/min. These combine to result in TCAL of 3.37 kcal/min. At this particular R value, 84.4% of these calories are derived from fat (see Table 1). This results in FCAL of 2.84 kcal/min. At 55%, the same subject demonstrates a TCAL of 6.29 kcal/min, and a FCAL of 2.25 kcal/min, based on an R value of .89 and a $\dot{V}O_2$ of 1.28 L/min. Using the criteria, for example, that a complete exercise bout is to expend 300 kcal, Subject No. 5 would have to exercise for 89 minutes at 30% of FC, and for 48 minutes at 55% of FC in order to expend the 300 kcal. During such an exercise bout at 30% of FC, 252.8 of the 300 kcal would be derived from fat. At 55% of FC, 108 kcal of the 300 kcal would be derived from fat. The results for Subject No. 5 are given in Table 5. Over the course of one year, assuming three exercise sessions per week, 52 weeks in one year, and 300 kcal per exercise session, a total of 46,800 kcal would be expended. Between the two different intensities, there would be a difference of 22,588 kcal of fat consumed, with more fat being consumed at 30% of FC. Given that one gram of fat equals nine kcal, this would equal approximately 2.5 kg (5.5 lbs.) of fat. Table No. 6 shows the results based on study averages. The results shown in Table No. 6 would yield a difference of 15,132 kcal (1.7 kg/3.7 lbs.) of fat being expended over the course of one year.

TABLE 5

COMPARISON OF FAT USE FOR A SINGLE SUBJECT:
CONSTANT 300 KCAL EXPENDITURE
AT DIFFERING INTENSITIES

Parameter	30% F.C.	55% F.C.
R Value	.75	.84
$\dot{V}O2$ (L/min)	0.71	1.28
Total kcal/min	3.37	6.29
Fat kcal/min	2.84	2.25
Min. to Spend 300 kcal	89	48
Total fat kcal expenditure	253	108

TABLE 6

COMPARISON OF FAT USE USING ALL STUDY DATA:
CONSTANT 300 KCAL EXPENDITURE
AT DIFFERING INTENSITIES

Parameter	30% F.C.	55% F.C.
R Value	0.77	0.86
$\dot{V}O2$ (L/min)	0.73	1.34
Total kcal/min	3.47	6.51
Fat kcal/min	2.73	2.99
Min. to Spend 300 kcal	86	46
Total fat kcal expenditure	235	138

These differences are theoretical, and may or may not accurately reflect actual losses of body fat. However, the fact remains that a difference does seem to be present, and that, over time, it may prove to be substantial in terms of increase body fat loss

At even higher intensities, and thus higher R values, fat use would be expected to decrease while total caloric expenditure would rise. Again, this characteristic of lower intensity exercise may or may not result in an actual enhancement of fat loss compared to higher intensity exercise.

As mentioned previously, fat consumption was higher for some subjects at 30% FC versus 55% FC. However, this is the one parameter in which there was no significant difference at the .01 level ($p>.05$). Fat utilization, per minute, was basically the same at 30%, 41%, and 55% of FC. This fact, coupled with the information presented above, would suggest that 55% of FC would be a more desirable exercise intensity than either 30% or 41% of FC, because total caloric expenditure would be greater. Also, in fact, fat consumption was slightly higher at 55% of FC, even thought there is no statistical significance. However, it could also be argued, based on the facts presented above, that 30% of FC would be equally as beneficial as 55% of FC in terms of fat consumption since there is no significant difference in FCAL between the two exercise levels. The time spent at 30% of FC would have to be extended in order to equal the total caloric expenditure experienced at 50% of FC, but total fat expenditure would be increased substantially. An additional aspect of this argument is that lower intensity exercise is generally tolerated better by exercisers, and thus compliance is likely to improve (Nieman, 1990).

CHAPTER V

SUMMARY, FINDINGS, AND RECOMMENDATIONS

Summary

Recently, low-intensity exercise has been promoted by some fitness professionals as a pain-free way to lose body fat, and as possibly a way to lose fat faster than by exercising at higher intensities. This notion is based upon the physiological principle that lower intensities of work utilize higher percentages of fat as a metabolic fuel, as opposed to carbohydrates, which are used predominantly at higher intensities. In response to these claims, other professionals are stating that these are questionable notions, and are providing studies which demonstrate no differences in body fat loss after programs of low- versus high-intensity exercise. However, no investigation has attempted to identify an exercise intensity at which the oxidation of fat is maximized, nor has any investigation examined physiological responses to differing low-level exercise intensities with respect to substrate utilization in terms of kcal/min.

Therefore, the purpose of this study was to examine differences in substrate utilization at differing levels of low- and moderate-intensity exercise. These differences could then be used to make inferences about long-term use of low-intensity exercise in terms of fat kcal used.

Findings

Based on the hypothesis stated and the limits of this study, the following findings were determined:

1. There is no significant difference in FCAL at 30%, 41%, and 55% of FC.

2. There is a significant difference in CCAL at 30%, 41%, and 55% of FC.

3. There is a significant difference in TCAL at 30%, 41%, and 55% of FC.

4. There is a significant difference in HR at 30%, 41%, and 55% of FC.

5. There is a significant difference in $\dot{V}O_2$ at 30%, 41%, and 55% of FC.

6. There is a significant difference in R value at 30%, 41%, and 55% of FC.

7. There is a significant difference in exercise intensity, expressed as %FC, at 30%, 41%, and 55% of FC.

Recommendations

Based on the data collected and the conclusions reached, it is evident that additional research is needed to further investigate the effects of low- and moderate-intensity exercise upon body fat loss and substrate utilization.

When undertaking these investigations it would be desirable to have a sample comprised of the type of subjects for whom this concept is targeted. That is, a sample of subjects whose primary purpose for exercise is the reduction of body fat. Also, additional studies should conduct evaluations of the effects produced by long-term programs of low- and moderate-intensity exercise regimes.

Finally, and ideally, investigations in this area should be long term, spanning a year or more. Only with this length of time will real differences, in terms of body fat loss, be significant.

Additional research in this area is warranted in order to evaluate the potential benefits of low-intensity exercise in terms of substrate utilization, body fat loss, and, ultimately, an improved sense of well-being.

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APPENDIXES

APPENDIX A

INFORMED CONSENT DOCUMENTS

Oklahoma State University
School of HPEL
Informed Consent Form

Purpose: The purpose of this study is to determine the relationship between two exercise bouts at commonly recommended exercise intensities with respect to the amount of fat burned as fuel during each. This study involves research carried out under the supervision of Dr. Frank A. Kulling, Asst. Prof., HPEL, and Mr. David Atkins, graduate student, HPEL.

Explanation and Purpose of Tests: Each subject will complete a 4 day dietary recall. Each subject will have completed, within 6 months of testing, an OSU Wellness Center screening. This screening will be at no cost to the subject. This screening includes: health risk appraisal; blood pressure; fingerstick total cholesterol; height; weight; and pinch caliper body fat determination. You will signed/will have signed a separate, approved, informed consent form for this screening; however, you must indicate willingness to release screening results to Dr. Kulling and Mr. Atkins in order to evaluate your health risk and acceptability for this study. You will be accepted for inclusion if you are "apparently healthy". If you are not, reasons for this will be explained to you along with recommendations for further testing and/or physician intervention. Any subject for whom physician intervention is recommended will be referred to the OSU health center.

Each subject will complete a sub-maximal step test in order to determine "fitness category". For this test, the YMCA Step-test protocol will be used. This involves you stepping up and down from a 12 inch bench at the rate of 24 steps/minute, for 3 continuous minutes. The intensity of this will be comparable to walking. Immediately following this test, your heart rate will be taken for 1 minute to determine fitness level. To be included in this study, you must possess an "above average" to "good" fitness level (88 to 116 beats/minute). If your determined fitness level is above or below this range, you will not be included as a subject in this study. This criterion is imposed to minimize subject variability and strengthen experimental design and is not meant to imply a subjective evaluation of results. If you desire, an oral evaluation of your step test results, relative to others your age, will be provided you regardless of your participation in this study.

Assuming you posses "above average" to "good" fitness as determined above, you will be scheduled for and complete a maximal exercise test. This will be accomplished on a motorized treadmill, which will undergo increases in speed and grade at regular intervals. Initially, your physical effort will be light, but as the treadmill grade and speed increase, the effort will become harder until fatigue or shortness of breath occurs, requiring the test to stop. Other symptoms such as pain, muscular discomfort, dizziness, and nausea are also indications to stop the test. During this test your heart rate and electrocardiogram will be constantly monitored. Blood pressure will be taken every 3-5 minutes during testing. A rating of perceived exertion will be recorded every 2-3 minutes. You will be fitted for and wear a mouthpiece and breathing valve during testing so your expired air samples can be collected and analyzed every 15 seconds. This expired air will provide information on the mixture of carbohydrate and fat burned as fuel. The mouthpiece and valve should not cause you any discomfort.

An additional treadmill exercise bout, consisting of three parts, will be administered following the maximal test. There will be several days between the maximal test and the second test. This will be similar in nature to the maximal test but will not involve maximal effort. Each part of the second test will last about 10 minutes, and the intensity for each part will be calculated from the results of the maximal test. One part will be at a intensity lower than is recommended to improve cardiovascular fitness and will be at a slow walk with very little incline. The second part will be at a slightly higher intensity and will involve slightly more incline. The third part increases in incline even further.

Possible Risks: The step test and treadmill exercise bout equivalent to walking are considered exercise of moderate intensity and do not present any risks except to those with the most severe forms of heart disease. The maximal treadmill test and treadmill exercise bout equivalent to jogging are considered exercise of vigorous intensity. This intensity presents risk to those who have any form of cardiovascular disease and to those who are at risk for cardiovascular disease. There has not been a single case reported in literature of a death or a life threatening complication occurring from a maximal exercise test performed on an apparently healthy person. Since your participation is predicated upon your status as apparently healthy, your risk of death or life threatening complication as a result of your participation is incalculably small. Nevertheless, your tests will be conducted and monitored by personnel who meet or exceed competency and certification requirements as set forth by the American College of Sports Medicine. These individuals have demonstrated ability to recognize and correctly respond to potentially dangerous situations arising from exercise testing of patients with cardiovascular disease. The realistic risk to you from your participation in this study is the possible discomfort associated with maximal, physical effort. The discomfort, if any, will be dependent upon individual perceptual differences. To minimize possible perceptual differences, you will be instructed to provide a rating of perceived exertion, thus minimizing the possibility of an overly difficult test. You may experience temporary muscle pain or stiffness, particularly following the vigorous tests, however warm-up preceding testing and cool-down following testing will minimize this possibility. In any event, the muscle discomfort should not last longer than 48 hours following exertion.

Benefits of Testing: (1) The Wellness Center screening will provide valuable information concerning your state of health and future health risk. (2) The step test and maximal treadmill test will provide valuable information concerning your cardiovascular fitness level. (3) This study will provide you with the exercise intensity at which you burn the largest amount of fat. (4) This study will add to the existing body of knowledge concerning exercise and the use of foodstuffs fuel. (5) This study will provide data for graduate student theses, dissertations and independent research.

Confidentiality of Records: Information and data collected by personnel associated with this study will be treated as privileged and confidential. Data may be used, in the aggregate, for presentations, articles, books, abstracts and other forums for the presentation and discussion of research related to exercise science and metabolism of foodstuff; however, data will not be associated or identified by name.

Affirmation/Consent/Waiver: My signature below indicates: (1) I have read and understand or received satisfactory explanation of this document and its contents. (2) My participation is predicated upon me being apparently healthy and of moderate fitness. (3) My participation in this study is completely voluntary and I may withdraw at any time without fear of prejudice or penalty by contacting Dr. Kulling or Mr. Atkins. (4) I provide Dr. Kulling and/or Mr. Atkins permission to access my OSU Wellness Center health screening results to determine my health status. (5) I authorize Dr. Kulling and others, chosen by Dr. Kulling to be competent, qualified and certified, to administer tests and collect, analyze and interpret data and present and publish findings arising from this study, providing my name is not associated with findings. (6) I will not receive any financial remuneration from participation in this study or publications arising from this study. (7) I may contact Dr. Kulling at 744-6753 (work) or 372-4266 (home) or Mr. Atkins at 744-9355 (work) or 624-8990 (home) to report anything adverse about my participation in or the effects of this study. (8) I may contact the office of University Research Services, at 001 Life Sciences East (744-9991) concerning my rights as a research subject. (9) If I sustain an injury resulting from my participation in this study, I will receive medical without any physician fee as long as OSU

Health Center personnel/physicians are utilized. I will be expected to pay costs associated with any treatment or diagnostic services. If I elect to utilize other medical personnel, the expense will be mine. (10) I will receive a verbal briefing and have additional opportunity to read this form just before each of the tests I undergo. (11) I have not waived any of my legal rights or released this institution from liability for negligence.

_______________________________(signed) ______________(date)

______________________________(witness) ______________(date)

OKLAHOMA STATE UNIVERSITY
WELLNESS CENTER

INFORMED CONSENT FOR EXERCISE TEST

EXPLANATION OF TESTS

The exercise test you are about to undergo is to determine your functional capacity and to aid in the evaluation of your heart and in the diagnosis of any symptoms you may be having that may be related to the function of your heart. It will be determined, prior to testing, that this evaluation is appropriate and safe for you. The test consists of gradually increasing effort and it will be carefully monitored by a physician or by Wellness Center personnel, specially trained in exercise testing.

During exercise testing your blood pressure, heart rate, and electrocardiogram will be constantly monitored. These measurements will provide important information regarding the state of your heart and your cardiovascular fitness. Before you undergo testing you will have an interview and will have completed the screening process.

You will perform the exercise test on a motor-driven treadmill at a comfortable walking speed. Initially your physical effort will be relatively light, but as the treadmill speed and incline are gradually increased, the effort will become harder until fatigue or shortness of breath occur, which are indications to stop exercise. Other symptoms, such as chest pain, muscular discomfort or loss of balance are also indications to stop. In addition, you should not continue the test if you have any other significant feelings of discomfort.

There exists the possibility of certain undesirable changes occurring during the exercise test. They include abnormal blood pressure, pulse rate and electrocardiographic response, and in very rare instances, heart attack or fatality. Every effort will be made to minimize any potential hazard by increasing the work effort slowly, and through continuous observation during testing. Emergency equipment is readily available to deal with unusual situations which may arise.

CONSENT OF PATIENT

The information which is obtained will be treated as privileged and confidential and will not be released or revealed to any non-medical person without your express written consent. The information will, however, be treated in an aggregate manner to provide group information as necessary.

I have read the foregoing and I understand it. Any questions which may have occurred to me have been answered to my satisfaction. I understand I may withdraw from and discontinue this test at any time during its performance.

PATIENT______________________________ DATE____________________

WITNESS______________________________ PHYSICIAN_______________

APPENDIX B

SAMPLE RAW DATA

Real-time Report During Second Treadmill Test

NAME:
ID #:
DATE: 03/05/93
TIME: 11:16 AM
DOB : 06-16-70

Test Time	Speed MPH	Grade %	Heart Rate	KCAL /min	Work Watts	RR /min	VEO2	VE BTPS	VO2 STPD	VCO2 STPD	R	VO2 %PM	BP dias	BP syst	METS	VO2 /KG
0:20	0.0	0.0	86	1.69	0	26	36	13.0	0.36	0.26	0.73	15			1.40	4.9
0:40	2.2	0.0	85	2.95	0	25	26	16.6	0.63	0.42	0.66	27			2.47	8.6
1:00	3.0	0.0	91	3.70	0	29	25	20.1	0.79	0.51	0.65	33			3.11	10.9
1:20	3.0	0.0	92	3.98	0	31	24	20.3	0.86	0.54	0.62	36			3.36	11.8
1:40	3.0	0.0	95	4.24	0	35	24	21.6	0.91	0.58	0.63	38			3.57	12.5
2:00	3.0	0.0	94	4.23	0	27	23	20.8	0.91	0.59	0.64	38			3.56	12.5
2:20	3.0	0.0	91	4.79	0	30	22	22.8	1.03	0.67	0.65	43			4.02	14.1
2:40	3.0	0.0	89	4.39	0	28	24	22.8	0.93	0.65	0.70	39			3.65	12.8
3:00	3.0	0.0	93	4.92	0	29	24	25.1	1.05	0.72	0.69	44			4.09	14.3
3:20	3.0	0.0	91	4.61	0	27	24	23.7	0.97	0.70	0.72	41			3.80	13.3
3:40	3.0	0.0	89	4.55	0	30	25	24.1	0.96	0.68	0.71	41			3.77	13.2
4:00	3.0	0.0	91	4.16	0	32	25	22.1	0.88	0.63	0.71	37			3.44	12.0
4:20	3.0	0.0	86	4.57	0	29	23	22.3	0.97	0.67	0.68	41			3.81	13.3
4:40	3.0	0.0	93	4.66	0	31	24	23.8	0.99	0.70	0.71	42			3.86	13.5
5:00	3.0	0.0	93	4.31	0	26	25	22.8	0.91	0.67	0.74	38			3.54	12.4
5:20	3.0	0.0	90	5.05	0	29	25	26.4	1.06	0.77	0.72	45			4.16	14.6
5:40	3.0	0.0	91	4.52	0	33	27	25.9	0.94	0.73	0.78	40			3.69	12.9
6:00	3.0	0.0	91	4.55	0	29	26	25.1	0.95	0.72	0.76	40			3.72	13.0
6:20	3.0	0.0	98	4.90	0	30	26	27.0	1.03	0.77	0.75	43			4.02	14.1
6:40	3.0	0.0	93	3.81	0	26	24	19.0	0.80	0.59	0.73	34	30% FC		3.14	11.0
7:00	3.0	0.0	100	5.03	0	32	26	26.9	1.05	0.79	0.75	44			4.13	14.4
7:20	3.0	0.0	95	3.45	0	28	25	17.8	0.72	0.54	0.75	30			2.83	9.9
7:40	3.0	0.0	89	4.31	0	28	24	21.7	0.91	0.67	0.74	38			3.54	12.4
8:00	3.0	0.0	94	3.95	0	30	24	19.9	0.83	0.60	0.72	35			3.26	11.4
8:20	3.0	3.4	97	4.97	32	31	24	25.1	1.05	0.76	0.73	44			4.10	14.3
8:40	3.0	4.5	101	4.86	43	32	25	25.7	1.02	0.77	0.76	43			3.98	13.9
9:00	3.0	4.5	108	5.88	43	30	23	28.2	1.24	0.89	0.72	52			4.86	17.0
9:20	3.0	4.5	106	5.36	43	26	23	25.4	1.13	0.82	0.73	48			4.42	15.5
9:40	3.0	4.5	108	6.47	43	28	21	28.8	1.37	0.98	0.72	57			5.34	18.7
10:00	3.0	4.5	108	5.47	43	28	22	25.7	1.15	0.84	0.73	48			4.50	15.8
10:20	3.0	4.5	108	6.17	43	26	20	25.9	1.30	0.93	0.71	55			5.10	17.9
10:40	3.0	4.5	111	6.78	43	31	22	31.0	1.42	1.06	0.75	60			5.57	19.5
11:00	3.0	4.5	112	6.50	43	28	23	30.9	1.35	1.06	0.78	57			5.29	18.5
11:20	3.0	4.5	111	6.03	43	26	22	27.8	1.26	0.97	0.77	53			4.92	17.2
11:40	3.0	4.5	109	5.94	43	29	22	27.1	1.24	0.94	0.76	52			4.86	17.0
12:00	3.0	4.5	111	5.78	43	31	22	27.1	1.21	0.93	0.77	51			4.72	16.5
12:20	3.0	4.5	111	6.37	43	30	21	28.3	1.34	1.00	0.75	56			5.23	18.3
12:40	3.0	4.5	112	7.01	43	29	22	32.7	1.46	1.14	0.78	61			5.71	20.0
13:00	3.0	4.5	111	6.14	43	31	24	30.9	1.26	1.05	0.83	53			4.94	17.3
13:20	3.0	4.5	113	6.29	43	27	23	30.5	1.30	1.05	0.81	55	45% FC		5.09	17.8
13:40	3.0	4.5	112	6.04	43	30	24	30.3	1.25	1.02	0.82	53			4.88	17.1
14:00	3.0	4.5	111	6.15	43	24	22	28.4	1.28	1.00	0.79	54			5.00	17.5
14:20	3.0	4.5	111	6.13	43	25	22	27.8	1.28	1.00	0.78	54			4.99	17.5
14:40	3.0	4.5	114	6.34	43	31	23	30.8	1.31	1.05	0.80	55			5.14	18.0
15:00	[illegible]	7.6	113	6.13	72	31	24	30.9	1.26	1.04	0.82	53			4.95	17.3
[illegible]	[illegible]	[illegible]	121	6.71	82	29	24	32.7	1.39	1.12	0.81	58			5.43	19.0

NAME:
DATE: 03/05/93 TIME: 11:16 AM

ID #:
DOB : 06-16-70

Test Time	Speed MPH	Grade %	Heart Rate	KCAL /min	Work Watts	RR /min	VEO2	VE BTPS	VO2 STPD	VCO2 STPD	R	VO2 %PM	BP dias	BP syst	METS	VO2 /KG
15:40	3.0	8.5	121	7.19	82	31	21	32.0	1.50	1.15	0.76	63			5.88	20.6
16:00	3.0	8.5	124	7.23	82	32	21	31.9	1.51	1.16	0.77	64			5.91	20.7
16:20	3.0	8.5	122	7.27	82	34	21	31.4	1.51	1.18	0.78	64			5.92	20.7
16:40	3.0	8.5	122	7.96	82	29	19	31.0	1.67	1.25	0.75	70			6.53	22.9
17:00	3.0	8.5	125	8.68	82	31	21	38.2	1.80	1.45	0.81	76			7.03	24.6
17:20	3.0	8.5	127	8.00	82	34	23	37.9	1.64	1.38	0.84	69			6.42	22.5
17:40	3.0	8.5	129	8.04	82	32	22	37.1	1.65	1.38	0.83	70			6.47	22.7
18:00	3.0	8.5	124	7.46	82	37	22	33.3	1.54	1.25	0.81	65			6.03	21.1
18:20	3.0	8.5	126	8.43	82	30	22	38.0	1.74	1.44	0.83	73			6.79	23.8
18:40	3.0	8.5	130	9.54	82	34	24	41.2	1.75	1.50	0.86	74			6.83	23.9
19:00	3.0	8.5	129	8.25	82	34	24	40.0	1.69	1.45	0.86	71			6.60	23.1
19:20	3.0	8.5	129	7.95	82	32	22	35.4	1.64	1.34	0.81	69			6.42	22.5
19:40	3.0	8.5	129	8.34	82	32	23	38.9	1.71	1.45	0.85	72			6.69	23.4
20:00	3.0	8.5	128	7.44	82	36	22	33.4	1.54	1.25	0.81	65	60% FC		6.01	21.0
20:20	3.0	8.5	130	8.16	82	33	23	37.7	1.68	1.41	0.84	71			6.56	22.9
20:40	3.0	8.5	130	8.95	82	33	23	38.1	1.65	1.41	0.85	69			6.44	22.5
21:00	3.0	8.5	132	8.38	82	33	22	38.2	1.72	1.44	0.84	73			6.74	23.6
21:20	3.0	8.5	131	8.43	82	33	23	39.4	1.73	1.46	0.84	73			6.77	23.7
21:40	3.0	8.2	132	8.78	79	35	24	43.1	1.79	1.55	0.86	76			7.02	24.6
21:54	2.5	0.0	130	8.88	0	35	23	41.8	1.83	1.52	0.83	77			7.14	25.0
*** Minimum Values ***																
0:20	0.0	0.0	85	1.69	0	24	19	13.0	0.36	0.26	0.62	15			1.40	4.9
*** Maximum Values ***																
21:54	3.0	8.5	132	8.88	82	37	36	43.1	1.83	1.55	0.86	77			7.14	25.0
*** Predicted Values *** (user specified)																
			196		206				2.35			100			11.39	39.9

Post-test Report From Second Treadmill Test

page - 1

NAME:
DATE: 03/05/93 TIME: 11:16 AM ID #:
DOB : 06-16-70

MAXIMUM PREDICTED VALUES FOR EXERCISE [in Jones, 1988]

Heart Rate : 196 bpm
Ventilation : 112 L/min
Oxygen Consumption : 2.4 L/min

Test Time	Grade %	Speed MPH	Heart Rate	ST Level	ST Slope	VE BTPS	RR /min	VO2 STPD	VCO2 STPD	R	VO2 /KG	VEO2	VECO2	BP syst	BP dias	KCAL /min
0:20	0.0	0.0	86	0.4	3	13.0	26	0.36	0.26	0.73	4.9	36	50			1.69
0:40	0.0	2.2	85	0.4	3	16.6	25	0.63	0.42	0.66	8.6	26	40			2.95
1:00	0.0	3.0	91	0.3	3	20.1	29	0.79	0.51	0.65	10.9	25	39			3.70
1:20	0.0	3.0	92	0.4	2	20.3	31	0.86	0.54	0.62	11.8	24	38			3.98
1:40	0.0	3.0	95	0.5	5	21.6	35	0.91	0.58	0.63	12.5	24	37			4.24
2:00	0.0	3.0	94	0.2	-0	20.8	27	0.91	0.59	0.64	12.5	23	36			4.23
2:20	0.0	3.0	91	0.3	3	22.8	30	1.03	0.67	0.65	14.1	22	34			4.79
2:40	0.0	3.0	89	0.4	4	22.8	28	0.93	0.65	0.70	12.8	24	35			4.39
3:00	0.0	3.0	93	0.5	3	25.1	29	1.05	0.72	0.69	14.3	24	35			4.92
3:20	0.0	3.0	91	0.5	4	23.7	27	0.97	0.70	0.72	13.3	24	34			4.61
3:40	0.0	3.0	89	0.4	7	24.1	30	0.96	0.68	0.71	13.2	25	35			4.55
4:00	0.0	3.0	91	0.4	4	22.1	32	0.88	0.63	0.71	12.0	25	35			4.16
4:20	0.0	3.0	86	0.3	2	22.3	29	0.97	0.67	0.68	13.3	23	34			4.57
4:40	0.0	3.0	93	0.4	1	23.8	31	0.99	0.70	0.71	13.5	24	34			4.66
5:00	0.0	3.0	93	0.4	6	22.8	26	0.91	0.67	0.74	12.4	25	34			4.31
5:20	0.0	3.0	90	0.5	7	26.4	29	1.06	0.77	0.72	14.6	25	34			5.05
5:40	0.0	3.0	91	0.3	5	25.9	33	0.94	0.73	0.78	12.9	27	35			4.52
6:00	0.0	3.0	91	0.5	6	25.1	29	0.95	0.72	0.76	13.0	26	35			4.55
6:20	0.0	3.0	98	0.5	5	27.0	30	1.03	0.77	0.75	14.1	26	35			4.90
6:40	0.0	3.0	93	0.4	4	19.0	26	0.80	0.59	0.73	11.0	24	33			3.81
7:00	0.0	3.0	100	0.3	2	26.9	32	1.05	0.79	0.75	14.4	26	34			5.03
7:20	0.0	3.0	95	0.4	4	17.8	28	0.72	0.54	0.75	9.9	25	33			3.45
7:40	0.0	3.0	89	0.4	4	21.7	28	0.91	0.67	0.74	12.4	24	32			4.31
8:00	0.0	3.0	94	0.3	2	19.9	30	0.83	0.60	0.72	11.4	24	33			3.95
8:20	3.4	3.0	97	0.2	2	25.1	31	1.05	0.76	0.73	14.3	24	33			4.97
8:40	4.5	3.0	101	0.3	3	25.7	32	1.02	0.77	0.76	13.9	25	33			4.86
9:00	4.5	3.0	108	0.4	4	28.2	30	1.24	0.89	0.72	17.0	23	32			5.88
9:20	4.5	3.0	106	0.6	6	25.4	26	1.13	0.82	0.73	15.5	23	31			5.36
9:40	4.5	3.0	108	0.3	4	28.8	28	1.37	0.98	0.72	18.7	21	29			6.47
10:00	4.5	3.0	108	0.2	2	25.7	28	1.15	0.84	0.73	15.8	22	31			5.47
10:20	4.5	3.0	108	0.2	9	25.9	26	1.30	0.93	0.71	17.9	20	28			6.17
10:40	4.5	3.0	111	0.5	7	31.0	31	1.42	1.06	0.75	19.5	22	29			6.78
11:00	4.5	3.0	112	0.5	8	30.9	28	1.35	1.06	0.78	18.5	23	29			6.50
11:20	4.5	3.0	111	0.6	9	27.8	26	1.26	0.97	0.77	17.2	22	29			6.03
11:40	4.5	3.0	109	0.6	7	27.1	29	1.24	0.94	0.76	17.0	22	29			5.94
12:00	4.5	3.0	111	0.2	8	27.1	31	1.21	0.93	0.77	16.5	22	29			5.78
12:20	4.5	3.0	111	0.0	9	28.3	30	1.34	1.00	0.75	18.3	21	28			6.37
12:40	4.5	3.0	112	0.1	6	32.7	29	1.46	1.14	0.78	20.0	22	29			7.01
13:00	4.5	3.0	111	0.2	8	30.9	31	1.26	1.05	0.83	17.3	24	29			6.14
13:20	4.5	3.0	113	0.2	10	30.5	27	1.30	1.05	0.81	17.8	23	29			6.29
13:40	4.5	3.0	112	0.5	12	30.3	30	1.25	1.02	0.82	17.1	24	30			6.04
14:00	4.5	3.0	111	0.7	14	28.4	24	1.28	1.00	0.79	17.5	22	28			6.15
14:20	4.5	3.0	111	0.3	3	27.8	25	1.28	1.00	0.78	17.5	22	28			6.13
14:40	4.5	3.0	114	[illegible]	5	30.2	31	1.31	1.05	0.80	18.0	23	29			[illegible]

NAME: ID #:
DATE: 03/05/93 TIME: 11:16 AM DOB : 06-16-70

Test Time	Grade %	Speed MPH	Heart Rate	ST Level	ST Slope	VE BTPS	RR /min	VO2 STPD	VCO2 STPD	R	VO2 /KG	VEO2	VECO2	BP syst	BP dias	KCAL /min
15:00	7.6	3.0	113	-0.1	11	30.9	31	1.26	1.04	0.82	17.3	24	30			6.13
15:20	8.5	3.0	121	0.5	13	32.7	29	1.39	1.12	0.81	19.0	24	29			6.71
15:40	8.5	3.0	121	0.7	11	32.0	31	1.50	1.15	0.76	20.6	21	28			7.19
16:00	8.5	3.0	124	0.6	12	31.9	32	1.51	1.16	0.77	20.7	21	28			7.23
16:20	8.5	3.0	122	0.6	12	31.4	34	1.51	1.18	0.78	20.7	21	27			7.27
16:40	8.5	3.0	122	1.0	13	31.0	29	1.67	1.25	0.75	22.9	19	25			7.96
17:00	8.5	3.0	125	0.7	14	38.2	31	1.80	1.45	0.81	24.6	21	26			8.68
17:20	8.5	3.0	127	0.8	15	37.9	34	1.64	1.38	0.84	22.5	23	27			8.00
17:40	8.5	3.0	129	0.7	13	37.1	32	1.65	1.38	0.83	22.7	22	27			8.04
18:00	8.5	3.0	124	1.0	16	33.3	37	1.54	1.25	0.81	21.1	22	27			7.46
18:20	8.5	3.0	126	1.1	16	38.0	30	1.74	1.44	0.83	23.8	22	26			8.43
18:40	8.5	3.0	130	0.6	15	41.2	34	1.75	1.50	0.86	23.9	24	27			8.54
19:00	8.5	3.0	129	0.9	19	40.0	34	1.69	1.45	0.86	23.1	24	28			8.25
19:20	8.5	3.0	129	0.8	17	35.4	32	1.64	1.34	0.81	22.5	22	26			7.95
19:40	8.5	3.0	129	0.9	16	38.9	32	1.71	1.45	0.85	23.4	23	27			8.34
20:00	8.5	3.0	128	0.8	16	33.4	36	1.54	1.25	0.81	21.0	22	27			7.44
20:20	8.5	3.0	130	0.7	16	37.7	33	1.68	1.41	0.84	22.9	23	27			8.16
20:40	8.5	3.0	130	0.6	15	38.1	33	1.65	1.41	0.85	22.5	23	27			8.05
21:00	8.5	3.0	132	0.7	16	38.2	33	1.72	1.44	0.84	23.6	22	27			8.38
21:20	8.5	3.0	131	0.8	16	39.4	33	1.73	1.46	0.84	23.7	23	27			8.43
21:40	8.2	3.0	132	0.7	16	43.1	35	1.79	1.55	0.86	24.6	24	28			8.78

APPENDIX C

DESCRIPTION OF INSTRUMENTS

AND TREADMILL PROTOCOL

DESCRIPTION OF INSTRUMENTS

Quinton Q-Plex Metabolic Cart

An automated open-circuit gas system manufactured by Quinton Instrument Company, Seattle, Washington. The subject is fitted with a valved mouthpiece, which directs their expired gases to the met-cart mixing chamber. Expired air is mixed and sampled by O_2 and CO_2 sensors. Flow rates are measured by an electronic flow meter.

Prior to each test, the met-cart is calibrated for gas concentration by using gas samples of known concentrations, and for volume by using a 3.000 liter air syringe.

The Q-plex is software driven, and is programmable to display and collect various physiological parameters. Reports are printed concurrently, with data being analyzed at a specified time interval. Subject data can be saved on either a hard or floppy disc, and reports can be generated from these.

Quinton Q5000

The Q5000 is an interfaced treadmill and 12-lead ECG/controller produced by Quinton Instrument Company, Seattle, Washington. The treadmill protocol is programmed into the software driven controller, and is controlled automatically. Hardcopy ECG collection is likewise programmable. Real time ECG and heart rate as well as speed and grade are displayed continuously on the ECG monitor.

Quinton Model 412 Automated Blood Pressure Cuff

The Model 412, produced by Quinton Instrument Company, Seattle, Washington, is an automated blood pressure cuff with built in microphones. The microphones, which are located in the cuff itself, are placed over the brachial artery. The controller unit inflates and deflates the cuff, and the microphones detect Korotkoff sounds. The controller unit is interfaced with the Q5000, and is programmable to take readings at different time intervals.

Q5000 PROTOCOL

Treadmill Protocol - Substrate Study

Stage	Speed (mph)	Grade (%)	Duration (min:sec)	METS
warm-up	2.1	0.0	5:00	1.9
1	3.0	0.0	2:00	3.3
2	3.0	3.0	2:00	4.5
3	3.0	5.0	2:00	5.4
4	3.0	7.0	2:00	6.2
5	3.0	9.0	2:00	7.0
6	3.0	12.0	1:00	8.2
7	3.0	15.0	1:00	9.5
8	3.0	18.0	1:00	10.7
9	3.0	20.0	1:00	11.5
10	3.0	22.0	1:00	12.3
11	3.0	24.0	1:00	13.2
12	3.4	24.0	1:00	14.8
13	3.8	24.0	1:00	16.2
14	4.2	24.0	1:00	16.6
15	5.0	24.0	1:00	17.3
16	5.5	24.0	1:00	18.4
17	6.0	24.0	1:00	20.0

VITA

David L. Atkins

Candidate for the Degree of

Master of Science

Thesis: AN EVALUATION OF METABOLIC FUEL UTILIZATION AT DIFFERENT LOW AND MODERATE EXERCISE INTENSITIES

Major Field: Health, Physical Education, and Leisure

Biographical:

Personal Data: Born in Fullerton, California, July 13, 1965, the son of George and Yvonne Atkins

Education: Graduated from Weatherford High School, Weatherford, Oklahoma, in 1983; received Bachelor of Science Degree in Secondary Education from Oklahoma State University, Stillwater, Oklahoma, in May 1988; completed the requirements for the Master of Science Degree at Oklahoma State University, Stillwater, Oklahoma, in May 1993.

Professional Experience: Secondary and Middle School Teacher, Lorena Independent School District, Lorena, Texas; Teaching Assistant, Department of Health, Physical Education, and Leisure, Oklahoma State University, January 1991, to May 1991; Laboratory Graduate Assistant, OSU Wellness Center, Oklahoma State University, August 1991, to May 1993. Member ACSM.