ABSTRACT

Vils, James G. The energy cost of horizontal speedwalking in males, 20 to 40 years of age. M. S. in Adult Fitness/Cardiopulmonary Rehabilitation, 1987. 84 p. (Patricia L. Hutchinson, Ed.D.)

The primary question to be answered in this study was: what is the energy cost of horizontal speedwalking in males, 20 to 40 years of age? A sub-question was: what are the differences between speedwalking and running at four and five miles per hour? A second sub-question was: can a sufficient intensity level be elicited by speedwalking to produce aerobic fitness benefits in males under 50 years of age? Thirty-seven moderately-to highly-trained males ages 20 to 39 performed a symptom-limited graded exercise test (SL-GXT) and four randomly ordered submaximal tests consisting of:

1.) 4.0 mph speedwalking
2.) 4.0 mph running
3.) 5.0 mph speedwalking
4.) 5.0 mph running

Various physiological parameters including heart rate (HR), ratings of perceived exertion (RPE), and respiratory gas values of minute ventilation ($\dot{V}_E$), oxygen uptake ($\dot{V}O_2$), METs, and respiratory exchange ratio (RER) were recorded for each test. The energy cost of speedwalking at 4.0 mph was calculated to be 5.8 METs or 447.8 kilocalories per hour. At 5.0 mph, speedwalking elicited values of 9.3 METs or 737.6 kilocalories per hour. The energy cost of speedwalking proved to be considerably higher than values recorded by ACSM (1986) for conventional walking. A dependent t-test ($p < 0.05$) was used to determine the physiological differences between speedwalking and running at 4.0 and 5.0 mph. All physiological values ($\dot{V}_E$, $\dot{V}O_2$, METs, HR, and RER) at both speeds except for RPE at 4.0 mph showed significant differences ($p < 0.01$) between speedwalking and running. RPE seemed to be difficult for subjects to evaluate at the lower intensity speed. Examining intensity levels showed that speedwalking at 5.0 mph did produce aerobic benefits in individuals under 50 years of age. A test of proportions showed that 80% of the subjects speedwalking at 5.0 mph were able to achieve 65% of their maximal heart rate and 50% of their maximal MET level. Speedwalking at 4.0 mph, on the other hand, did not provide subjects with a sufficient intensity level to produce aerobic benefits. It was concluded that speedwalking can be an exercise alternative which provides aerobic fitness benefits in males under 50 years of age.

THE ENERGY COST OF HORIZONTAL SPEEDWALKING IN MALES, 20 TO 40 YEARS OF AGE

A Thesis Presented
to
The Graduate Faculty
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TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

CHAPTER I

INTRODUCTION

Public health surveys show that 40% to 50% of American men and women, 80 to 90 million people, do not engage in physical activity. "Blair says: If the people who take elevators and park as close as they can to the door could be persuaded to do, two or three 15 minute walks each day at a moderate pace, that would contribute more to the health of the nation than persuading another 10% to 15% to run 10-K (kilometer) races on weekends" (Norris, 1986, p. 21). A recent report examining the physical activity and other life style characteristics of 16,936 Harvard alumni showed lower total mortality in Harvard alumni who were more active. In addition, such disorders as obesity, osteoporosis, and hypertension were less prevalent (Paffenbarger, Hyde, Wing, & Hsieh, 1986).

Some of the reasons given for Americans low motivation and compliance to exercise is that activities do not meet the following criteria: convenient, enjoyment, able to exercise with friends, exercise success, exercise variety, time in ones' daily routine, and changes in seasons and weather (Campbell, Franklin, Freedson, Haskell, Rippe, & Ward, 1986). To be successfully accepted, an activity should not focus on any one aspect (intensity, frequency, or duration) but rather on the total caloric cost of exercise to improve and maintain fitness (Campbell et al., 1986).

Walking is now the number one participant sport in the United States.

> To provide the greatest health benefits, exercise programs need to be lifelong and consistent. Walking has a low injury rate, it is a sociable exercise, it can fit into a daily routine, and people of various fitness levels can walk together. For all these reasons, walking is an almost ideal form of exercise for a lifelong program (Campbell et al., 1986, p. 159).

Walking can be performed in a variety of styles and speeds. The styles include strolling (the slowest form), everyday walking, hiking, walk-climbing, speedwalking, backpacking, snowshoeing, and race walking (Yanker, 1983). Of the 70 million Americans who participate in some form of aerobic exercise, most (53%) are engaged in regular walking (Harvey, 1986). Walking requires no prior conditioning, it is inexpensive, and easy to perform. Walking also possesses less potential for injury than more stress producing exercises, such as running or aerobics (Brown, & Rodgers 1985; Cairns, 1985; Morris, 1984; Turbin, 1984; and Rogers, 1986). It has been shown that physical exercise should be progressive and maintain the body, not tend to over strain or destroy it, which may be the case with high stress aerobic dance and running (Brown, & Rodgers, 1985; Jones, 1986; and Yanker, 1983). Yanker (1983, pp. 20-21) states the following:

> Walking is a virtually injury free exercise. in fact, joint and muscle injuries and strains are perhaps the primary reason why people choose walking as an exercise. Such injuries result from improper joint alignment, strenuous exercises like jogging, and overused and overdeveloped muscles. Walking reduces the angular stresses on the body joints because the feet remain parallel to each other in a wider gait. The walker's parallel leg movement is the natural movement for the joints, which were built for a forward/backward motion and not a side-to-side angular motion.

The most significant disadvantage attributed to walking is that normal fast walking may not be of sufficient intensity to produce aerobic fitness benefits in males under 50 years of age (Porcari, Kline, Hintermeister, Freedson, Ward, Gurry, Ross, McCarron, & Rippe, 1986; and Yanker, 1983). This, along with the increased time commitment needed to attain similar aerobic benefits as those elicited by running, make walking less desirable for many Americans (Brown & Rodgers, 1985; and Campbell et al., 1986).

In order to alleviate these two problems, some researchers have proposed increasing the intensity of walking through the use of hand held weights or more familiarly termed Heavyhands. In a round table discussion by Campbell et al. (1986) Franklin reported that research indicates standard walking with hand held weights and vigorous arm movements increases the energy expended at any given speed by about 0.5 to 1.0 METs. More importantly, subjects who walked with 1 to 3 pound hand held weights and used vigorous arm movements achieved metabolic loads similar to those of slow jogging. However, vigorous arm movements had to be used. If an individual simply carried hand weights without the use of vigorous arm movements, the energy cost of walking was affected only slightly and could have just as easily been achieved by increasing the walking speed. Campbell et al. (1986) stated that hand held weights may possibly cause back problems. Because hand weights increase the inertia of the upper body, the back muscles must generate more force to change the upper body rotation. "Researchers on back problems and injury suggested that damage is often done when load and torque are increased at the same time" (Campbell et at., 1986, p. 151).

When asked by Freedson whether or not the vigorous arm movement alone would increase energy cost to the same degree as using heavyhands. Franklin stated that energy costs seemed to be more dependent on the arm swing than the weights themselves. Franklin also noted that vigorous arm movement alone would probably raise the metabolic cost of walking 0.5 to 1.0 METs but that so far to his knowledge no one has researched the arm swing without Heavyhands. A study by Cigala (1985) indicated that there was a significant difference between vigorous arm movement with Heavyhands, verses without at 3.0 miles per hour walking. Cigala found a MET level increase of 0.5 METs for every one pound increase in Heavyhand handles used (e.g., one pound hand weights verses 2 pound hand held weights increased MET values by 0.5 METs). More importantly, Cigala's study also showed a significant increase in the energy cost calculated for the vigorous arm movement when compared to that of normal walking.

Since walking with vigorous arm movements alone has been shown to increase energy cost of normal walking and since Heavyhands may be unsafe in regards to back problems, it is only logical we consider an alternative to standard walking styles as a training mode. Such a possibility may be speedwalking. Rowen & Laiken (1980) initially designed speedwalking as a simplified version of race walking. This geared up form of walking uses increased hip and arm movements to keep in synchronization with and allow for an increased step frequency. Speedwalking also requires that the front heel be planted at or near a 90 degree angle to the shin, and the arms be carried in the sagittal plane with the elbows held at a comfortable angle (e.g., at 45 to 90 degrees of flexion) (Rowen & Laiken 1980). The increased arm movement used in speedwalking for synchronization and increased stride frequency may provide the means of eliminating the two major problems limiting normal walking. However, currently there is no research which has established the energy cost or physiological benefits of speedwalking.

Along with improving one's fitness level, speedwalking may offer all the benefits listed above for walking (i.e., low injury rate, a sociable exercise, fits into a daily routine, and people of various fitness levels can speedwalk together). Like walking, speedwalking is very easy to perform. If one can walk, it follows that one can speedwalk (Rowen & Laiken, 1980). Because speedwalking enables one to walk at a faster speed with increased arm movements, it is thought that energy costs should also rise. To determine that speedwalking can be safely prescribed as an exercise alternative for individuals, the energy cost of speedwalking will be examined in this thesis.

Statement of the Problem

The primary question to be answered by this study was: what is the energy cost of horizontal speedwalking in males 20 to 40 years of age? A sub-question was: what are the differences between speedwalking and running at four and five miles per hour? A second sub-question was: can a sufficient intensity level be elicited by speedwalking to produce aerobic benefits in males under 50 years of age? The above two sub-questions relate to the two hypotheses listed on page 6.

Need for the Study

The need for low impact total body exercises that are inexpensive, convenient, and easily performed makes speedwalking a very viable consideration as an exercise alternative. Speedwalking may also prove beneficial to individuals plagued with hindering injuries from more strenuous forms of exercise such as running. Presently, no research establishing the metabolic cost and physiological effects of speedwalking has been done. A study evaluating these parameters would be helpful in determining the benefits of speedwalking and provide guidelines for safe exercise prescriptions.

Hypotheses

The following hypotheses relate to the two sub-questions presented in the statement of the problem and were offered for this study:

1). There will be no significant difference in oxygen consumption between speedwalking or running at four and five miles per hour.

2). Eighty percent of the subjects tested speedwalking will not obtain sufficient intensity levels to produce aerobic benefits (65% of their maximum heart rates and/or 50% of their maximal oxygen consumption values).

Assumptions

The following assumptions were made in this study:

1). That the subjects under study were all in good health.

2). That subjects put forth their best effort and were comfortable speedwalking following the one-week training session.

3). That the average oxygen consumption during the last three minutes of each exercise test represented a steady-state level.

4). That all subjects did not smoke or ingest food with exception of water, three hours prior to each test session.

5). That all equipment used (treadmill, BMMC, and ECG recorder) was calibrated accurately.

Delimitations

The following were delimitations of the study:

1). Subjects consisted of 37 healthy 20 to 40 year old male volunteers who exercised no less than 2 miles or 20 minutes three times a week.

2). All subject testing was to be completed two weeks following the training program.

3). Subjects could not be tested if they were on any type of medications altering heart rate

4). Subjects must have achieved a 9 MET level capacity or above on their maximal oxygen uptake test, without signs or symptoms of angina on their electrocardiogram, in order to be accepted in the study.

Limitations

The following was a limitation of the study:

1). The subjects' style of speed walking varied among individual subjects due to different body height, weight, and walking styles and may have affected the energy cost.

Definition of Terms

Aerobic Exercise - a physical activity during which the exercise intensity is easily sustained with little variability in heart rate response (e.g. walking, jogging, running, swimming, cycling, cross-country skiing, and skating) (American College of Sports Medicine (ACSM), 1980).

Beckman Metabolic Measurement Cart (BMMC) - a programmable automated open circuit system which analyzes expired air with a volume flow meter and two gas analyzers (OM-11 and LB-2) to determine oxygen and carbon dioxide concentrations, respectively. The calculations of oxygen consumption, respiratory exchange ratio, and minute ventilation are determined via the calculator which coordinates operation of the measurement system (Wilmore, Davis, & Norton, 1976).

Energy Cost - an amount of energy required by the body to perform an activity. Energy cost was estimated from the oxygen requirements of the exercise in this study. This value was expressed in $L \cdot min^{-1}$ or $ml \cdot kg^{-1} \cdot min^{-1}$ of oxygen consumed, or in METs (McArdle, Katch, & Katch, 1981).

Exercise Prescription - an individualized exercise program based on the person's current fitness and health status, with emphasis on intensity, frequency, duration, and type of exercise. Heart rate and oxygen uptake data obtained during a stress test are used to formulate the exercise prescription to insure that the individual does not exceed his/her exercise limitations which may be deemed unsafe (McArdle et al., 1981).

Jogging - slow, continuous running above a 15 minute mile (4.0 mph) but slower than a seven minute mile (8.6 mph). In this study terms jogging and running are used in the same context (ACSM, 1980).

Kilocalorie (kcal) - an energy unit of measure equal to the amount of heat required to raise the temperature of one kilogram of water one degree celsius (Fox & Mathews, 1981).

Maximum Oxygen Uptake ($\dot{V}O_{2max}$) - the highest rate at which oxygen can be taken up by the body tissues per minute during exercise. A respiratory quotient over 1.0 and/or a leveling off and drop in oxygen consumption was representative and used as the true maximal oxygen uptake in this thesis (McArdle et al., 1981).

Metabolic Equivalent (MET) - the amount of oxygen required by the body per minute under quiet resting conditions. One MET is equal to 3.5 milliliters of oxygen consumed per kilogram of body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$) (Fox & Mathews, 1981).

Net Energy Cost - the number of kilocalories expended for a given activity minus the number of kilocalories that would have been expended for an equivalent time period at rest (McArdle et al., 1981).

Ratings of Perceived Exertion - a subjective indicator or rating of degree of physical strain during a physical activity. The overall rating integrates information including signals elicited from peripheral working muscles and joints, the central cardiovascular and respiratory functions, and the central nervous system (Borg, 1982).

Race Walking - a form of heel and toe walking that incorporates arm and hip motion to increase stride length and speed. In race walking, the lead foot must be in contact with the ground before the back foot leaves the ground. Therefore, in every stride, there is a period of double contact when both feet are on the ground. Also, when race walking, the leg must be straight at the knee (locked) during the support phase of the stride; that is, when the leg is directly below the body (Kitchen, 1981).

Speedwalking - a simplified version of race walking that incorporates an increased arm motion in order to maintain synchronization with an increased step frequency. Speedwalking has also been termed health walking and/or power walking (Rowen & Laiken, 1980).

Steady-State - the physiological state where oxygen supply and demand are in balance. The oxygen consumption rises to a given level and then plateaus for the exercise session. In this study, steady-state was attained when oxygen consumption did not vary more than 150 ml per minute during collection of respiratory gases (Cigala, 1985).

Target Heart Rate (THR) - a heart rate (pulse rate) per minute during exercise that will produce significant cardiorespiratory benefits usually estimated to be 65% of the individuals maximal heart rate as indicated by ACSM (1986).

CHAPTER II

REVIEW OF RELATED LITERATURE

This study was designed to examine and compare the oxygen consumption of speedwalking and running at four and five miles per hour. The following topics will be reviewed in this chapter: calculation of energy expenditure under which steady-state exercise and ratings of perceived exertion are examined, physiological and psychological benefits of exercise, walking and running energy expenditure, and speedwalking benefits and energy expenditure.

Calculation of Energy Expenditure

When chemical energy is expended by the human body in performing work, an equal amount of energy is released by the working muscles in the form of heat, often referred to as the first law of thermodynamics (Fox & Mathews, 1981; McArdle et al., 1981). By measuring the amount of heat expended, scientists have been able to determine the amount of energy that the body requires to perform a given task (i.e., sleeping, sitting, or exercising). Human energy expenditure can be measured with a variety of techniques which are broadly classified as direct and indirect calorimetry (the measurement of heat). With direct calorimetry, heat energy, expressed as thermal equivalents or kilocalories (kcals), is measured directly with the aid of a calorimeter. This instrument is an airtight thermally insulated living chamber which measures heat produced and radiated by a person sleeping or exercising inside. The heat is absorbed and removed by a stream of cold water flowing at a constant rate through tubes coiled near the ceiling of the chamber. The difference in the temperature of the water entering and leaving the chamber represents the person's heat production. Humidified oxygenated air is continually circulated through the chamber while expired carbon dioxide is removed by chemical absorbents (Fox & Mathews, 1981; International Committee for the Standardization of Physical Fitness Tests (ICSPFT), 1974; McArdle et al., 1981). Although this method of determining energy expenditure is highly accurate, few physiology laboratories have either the space or funds required to install a calorimeter large enough to measure human energy expenditure, especially for sport and recreational activities (McArdle et al., 1981). The alternative method used for determining energy expenditure is indirect calorimetry. This method expresses energy expenditure in one of three ways: (1) total oxygen consumption ($\dot{V}O_2$) (2) metabolic equivalents (METs) and (3) respiratory quotient (R.Q.). Each method requires that the oxygen consumed by the body be calculated. "All energy metabolism in the body ultimately depends on the utilization of oxygen. Thus, by measuring a person's oxygen consumption under steady-rate conditions, it is possible to obtain an indirect estimate of energy metabolism" (McArdle et al., 1981, p. 95).

Oxygen Consumption

When one exercises, the muscles of the body use three energy sources to meet energy demands. (1) The immediate energy source is stored in the muscles themselves and used for short term explosive activity such as the 100-yard dash. Once this energy is exhausted it can not be replenished until one consumes oxygen. Therefore, after running a sprint one will be breathless for a brief time until the energy lost from the muscles can be restored. (2) The short-term energy source converts glucose (a carbohydrate in muscles) to lactic acid, a process critical to prolonged high intensity exercise such as running a quarter or half mile. As lactic acid accumulates though, the muscles fatigue and one's ability to exercise becomes impaired. (3) With the long-term energy source muscles use oxygen to convert carbohydrate and fat to energy (very small amounts of protein in some cases may also be converted). Since the long-term energy source requires oxygen, it is termed aerobic. Immediate and short-term energy sources produce energy without oxygen and are termed anaerobic (Stamford, 1985).

During a long workout, muscles need oxygen to convert carbohydrate and fat to energy. The harder the work, the more energy required to sustain the work thereby increasing the body's demand for oxygen. "The potential for prolonged exercise is exclusively due to an aerobic energy yield with a combustion of glucogen (and glucose) and free fatty acids. The rate of this combustion is dependent on and measured by the oxygen uptake" (Astrand, 1976, p. 55). Therefore, as a person increases the rate of work, there is a direct linear increase in the amount of oxygen used. Eventually the person will attain a level of work where he or she will be unable to increase oxygen uptake further as the oxygen delivery system (mainly cardiac output) has been taxed to its maximum. This peak level of oxygen uptake, where a further increase in the rate of work fails to increase oxygen uptake, is referred to as the maximal oxygen uptake ($\dot{V}O_{2max}$) (Guyton, 1986; and Wilmore, 1984). Most exercise activities, in order to gain an aerobic conditioning effect, are performed between 65 and 90 percent of $\dot{V}O_{2max}$ (ACSM, 1986). Guyton (1986) states that an average young man has an approximate resting oxygen consumption of 250 ml per minute. However, under maximal conditions oxygen consumption can increase to approximately the following average levels:

Untrained average male	3600 ml/min
Athletically trained average male	4000 ml/min
Male marathon runners	5100 ml/min

Maximal oxygen uptake values are greatly influenced by body size. Thus, $\dot{V}O_2$ is usually expressed relative to body weight, i.e., milliliter·kilogram^{-1}·minutes^{-1}. This allows a more equitable comparison between individuals of different sizes. $\dot{V}O_{2max}$ will also vary with age and sex. With aging, $\dot{V}O_{2max}$ decreases by approximately 3.5 ml·kg^{-1}·min^{-1} per decade, and this appears to be independent of the individual's level of training or fitness. Women demonstrate the same aging pattern and, in addition, have values that are typically 20 to 25% lower than men of equal age. This difference between sexes appears to be at least partly explained by differences in activity levels as opposed to specific sex-linked differences.

$\dot{V}O_{2max}$ values vary from highs of 80 to 95 ml·kg^{-1}·min^{-1} in cross-country skiers and long-distance runners, to lows of 40 ml·kg^{-1}·min^{-1} or less in the more sedentary athletes. The highest value recorded was 94 ml·kg^{-1}·min^{-1} for a champion Norwegian cross-country skier. The highest value recorded for a female athlete was 77 ml·kg^{-1}·min^{-1} for a Russian cross-country skier (Wilmore, 1984 p. 125)

Metabolic Equivalent (MET)

The metabolic equivalent (MET) represents the amount of oxygen consumed ($\dot{V}O_2$), per kilogram of body weight, per minute, under quiet resting conditions (also termed basal metabolic rate) (Fox & Mathews, 1981; Franklin, Pamatmat, Johnson, Scherf, Mitchell, & Rubenfire, 1983;

and Katch & McArdle, 1977). One MET is equal to 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (deVries, 1980; Fox & Mathews, 1981: Franklin et al., 1983; and McArdle et al., 1981). Presenting energy consumption in this manner provides a point of reference common to all individuals. For example: an exercise requiring 10 METs simply means that the oxygen consumed and energy expended is 10 times that of the 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ needed for rest or a $\dot{V}O_2$ of 35 $ml \cdot kg^{-1} \cdot min^{-1}$.

To calculate the MET level of an activity, oxygen consumption measured in $ml \cdot kg^{-1} \cdot min^{-1}$ must be known. This figure is then divided by one MET (3.5 $ml \cdot kg^{-1} \cdot min^{-1}$). The units cancel themselves out and the result is a value with no units. Thus the MET level of an activity is the ratio of exercising energy cost to that of the resting energy cost. Average workloads of various activities assessed in terms of METs is far easier to comprehend than expressing them in terms of $\dot{V}O_2$ or kcals (ACSM, 1980; and McArdle et al., 1981).

Respiratory Quotient (R.Q.)

Respiratory quotient is a measure of the ratio of the volume of carbon dioxide per minute produced to the volume of oxygen consumed per minute ($\dot{V}CO_2/\dot{V}O_2$), and it provides an indication of both the type of fuel metabolized and the amount of body heat generated while performing various activities. "The physiologic requirements for the performance of work involve a functional coupling of accelerated cardiovascular and respiratory activity to achieve gas (CO_2 and O_2) transport between the muscle cells and the atmosphere appropriate for the increased metabolic stress" (Wasserman & Whipp, 1975, p. 219). The ratio of the volume of

CO_2 produced ($\dot{V}CO_2$) to the volume of O_2 consumed ($\dot{V}O_2$) in oxidative metabolism varies with the substrate mixture undergoing oxidation. Carbohydrate is metabolized with an R.Q. of 1.0 and fat with an R.Q. close to 0.7 (McArdle et al., 1981; and Wasserman & Whipp, 1975). Protein is generally used as a metabolic fuel source in times of fasting or starvation (McArdle et al., 1981). It requires less oxygen for its breakdown than fats and produces an RQ of approximately 0.82. Even though protein metabolism is an important source of energy for the body during periods of starvation, only a minimal amount (3%) of protein energy is used under normal conditions (ICSPFT, 1974; McArdle et al., 1981). For this reason proteins are not considered in the calculations of kcals for R.Q. values. Instead, it is assumed that only carbohydrates and/or fats are being used (Fox & Mathews, 1981; McArdle et al., 1981).

Energy is released when water is formed (combining hydrogen and oxygen) during the metabolism of foods. The more hydrogen atoms per oxygen atoms contained in a substrate, the greater the ability of that substrate to produce energy. The fat substrate is able to provide more energy to the cell than carbohydrates for the sole reason that it has more hydrogen atoms per oxygen atoms. A typical carbohydrate, glucose, has the chemical make up $C_6H_{12}O_6$ compared to a typical fat, palmitic acid, which is $C_{16}H_{32}O_2$. Consequently, there are more hydrogen atoms in fat to combine with oxygen in forming water (H_2O). Therefore, when the body uses a given amount of fat, more energy is released (twice the number of kcals) than when it metabolizes the same amount of carbohydrate. Although fat contains more than twice the chemical energy of carbohydrate per gram, it also requires more oxygen to release each calorie of energy. When oxygen is limited, as happens with greater work intensities and increased cell metabolism, the body reacts by switching over more to carbohydrates to obtain the energy needed. Carbohydrates require the least amount of oxygen for metabolization and as a result, can be utilized more rapidly as an energy source than fats (Fox & Mathews, 1981).

Once the type of fuel utilization has been determined, calculation of body heat production or energy expenditure is accomplished by measuring the amount of heat that is produced when each of the various foodstuffs are burned in the presence of one liter of oxygen. Fox and Mathews (1981) obtained the following heat energy equivalents for the three foodstuffs: carbohydrate, 5.05 kcals; fat, 4.74 kcals; and protein, 5.20 kcals.

To assess the energy cost of a specific activity in Kcals per liter of oxygen, the exact R.Q. must be known (McArdle et al., 1981). Table 1 shows the nonprotein respiratory quotients and their corresponding thermal equivalents (kcals) per liter of oxygen used in the calculation of energy expenditure (McArdle et al., 1981 p. 101). By knowing the oxygen consumption in liters per minute and the thermal equivalents (Kcals) corresponding to the R.Q. value, the energy cost of the activity ($kcals \cdot min^{-1}$) can be determined by multiplying the two values.

Table 1. Nonprotein respiratory quotients and their corresponding thermal equivalents (kcals) per liter of oxygen, including the percentages of kcals derived from carbohydrates and fats.

NONPROTEIN R.Q.	KCAL PER LITER OXYGEN CONSUMED	PERCENTAGE OF KCALS DERIVED FROM CARBOHYDRATES	FATS
0.707	4.686	0.00	100.0
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	4.899	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	0.00

Steady-State Exercise

A steady-state condition is defined as the point during constant-load exercise that oxygen transport mechanisms are able to meet the tissues demands for oxygen uptake, waste product removal, and temperature regulation (Wasserman, Van Kessel, & Burton, 1967; and Stainsby & Barclay, 1970). Steady-state actually reflects a balance between the energy required by the working muscles and the rate of ATP production caused by aerobic metabolism. During this period it is the oxygen-consuming reactions (beta oxidation of fatty acids and/or the Krebs cycle) that supply the energy for exercise (McArdle et al., 1981; Wasserman et al., 1967). Although steady-state exercise is usually depicted by the leveling off or plateauing of oxygen consumption values ($\dot{V}O_2$), other leveling off values such as blood lactate concentration, heart rate, cardiac output, ventilation ($\dot{V}_E$), and core temperature have also been used to detect the occurrence of steady-state (ICSPFT, 1974). Astrand & Saltin (1961) reported that heart rate, cardiac output, ventilation, core temperature, and lactic acid concentrations in the blood show little variability during steady-state exercise. In contrast Scheen, Juchmes & Cession-Fossion (1981) announced that heart rate ventilation and lactic acid continue to increase with exercise time, making it difficult to determine the beginning of steady-state exercise. Of the four steady-state values examined, oxygen uptake ($\dot{V}O_2$) (remaining relatively stable) was the most accurate indicator of steady-state followed by lactic acid (Scheen et al., 1981). .ie ease of measurement and accurate response to exercise makes $\dot{V}O_2$ the preferred method of determining the occurrence oi steady-state during exercise (ICSPFT, 1974; and Scheen et al., 1981).

True steady-states or more accurately steady-rates, can be reached anywhere from three to six minutes after the exercise has started (Wipp &

Wasserman, 1972). Astrand & Saltin (1961 p. 971) advise "duration of work in studies of circulation and respiration during submaximal work should exceed five minutes". Likewise, Wasserman et al. (1967, p. 75) stated "a true steady-state is reached within four minutes for moderate work, but not in less than ten minutes, if at all, in the case of very heavy work". The time it takes to reach steady-state is dependent upon the subjects level of fitness and the intensity of work being performed (Scheen et al., 1981; and Whipp & Wasserman, 1972). A delay in steady-state $\dot{V}O_2$, an over all reduced $\dot{V}O_2$, and a prolonged, elevated recovery $\dot{V}O_2$ are all characteristics of a general lack of fitness (Whipp & Wasserman, 1972). If subjects of average fitness levels work at an intensity level 50-60% of their maximum oxygen uptake, steady-state values can be attained within three minutes. Above 60% of maximum oxygen intake, oxygen consumption continues to rise with time (ICSPFT, 1974; Wasserman et al., 1967; Wipp & Wasserman, 1972). "The steady-level of oxygen uptake ($\dot{V}O_2$) which is achieved during exercise is generally accepted as reflecting the energy cost of the exercise" (Stainsby & Barclay, 1970, p. 178). A study performed by Cigala (1985) used the criteria that less than a 150 ml difference in $\dot{V}O_2$ must appear for three consecutive minutes in order for a true steady-state to have occurred reflecting an accurate energy cost of exercise.

Accurate calculations of energy expenditure of an activity, using the indirect method, requires that the subject being tested reach a steady-state level of exercise. As one begins exercising it takes time for the body to adjust to the increased demand for energy. Once adjusted, the the body will continue to supply, at a steady rate, the amount of energy and oxygen needed for the given activity, providing the activity level remains constant. Oxygen uptake and other bodily functions can thus be accurately measured or recorded without variation, yielding accurate energy expenditure calculations.

Ratings of Perceived Exertion (RPE)

Until the development of the RPE scale, the only means physiologists had to regulate exercise intensity was through target heart rate and/or MET values. These methods at times proved to be difficult and cumbersome for some individuals to comprehend and use. For these reasons, and to help people to become more attuned to their bodies, Borg (1982) developed what is now known as the Ratings of Perceived Exertion (RPE) scale.

According to Borg (1973) the 15 point ratings scale correlates highly (.80 to .90) with heart rate in healthy people varying from light to heavy work. "The RPE values follow the heart rates very closely. For healthy middle-aged men doing moderate to hard work on a bicycle ergometer or treadmill, the heart rate should be about ten times the RPE value" (Borg, 1973, p. 91). The RPE response to graded exercise has also been shown to correlate highly with cardiorespiratory and metabolic variables such as oxygen uptake ($\dot{V}O_2$), ventilation, and blood lactate concentration (ACSM 1986; and Skinner, Hutsler, Bergsteinova, & Buskirk, 1973). American College of Sports Medicine (1986) states that the Borg scale is a valid and reliable indicator of physical exertion workloads performed under constant intensity exercise and therefore, can be used to predict and prescribe exercise intensity for endurance training.

"Using the Borg scale, a perceived exertion rating of 12 to 13 corresponds to approximately 60% of heart rate range. A rating of 16 corresponds to approximately 90% of the heart rate range. Consequently most participants should exercise at an intensity rated between 12 and 16 ("somewhat hard" to "hard")" (ACSM, 1986, p. 36). This 15 point numerical scale, ranging from 6-20, with a verbal description provided at every odd number, is presented in Table 2 (Borg, 1973, p. 92).

Table 2. Borg Ratings of Perceived Exertion (RPE) Scale.

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard

Findings indicate that normal subjects are capable of consistently identifying the differences between work loads varying by 150 kpm or greater by means of Borg's ratings of perceived exertion. These subjective estimates have also been shown to mirror the actual metabolic cost of work being performed (Morgan, 1973). There are exceptions to this generalization however. Neurotic, anxious, or depressed subjects appear to have difficulty in their perception of work intensity and it has been reported that extroverts tend to underrate work intensity at heavier work loads (Morgan, 1973). A study by Noble, Metz, Pandolf, Bell, Cafarelli, & Sime (1973) to determine how subjects would perceive walking and running at 4.0 mph found heart rates during walking to be less than those found for running at velocities lower than 4.0 mph. The curve intersected at 4.92 mph and the reverse occurred with heart rate above 4.92 mph. Perceived exertion showed a similar pattern except the curve intersected at a significantly lower speed 4.31 mph. Noble et al. (1973, p. 116) stated "although perceived exertion generally follows heart rate responses, local muscular discomfort at higher walking velocities is proposed as the factor responsible for the earlier perceptual intersection. Butts (1982) reported that subjects working at or close to their maximal heart rates elicited low correlations between RPE and heart rate. It was suggested that RPE responses in the middle range of work intensity are a more accurate reflection of heart rate than those recorded at the extremes (Butts, 1982).

Because of the high correlation with heart rate, RPE can also be used in conjunction with prescribed target heart rate to help individuals maintain and monitor specified heart rates and intensity levels. Once individuals understand and experience the heart rate - RPE relationship, heart rates can be monitored less frequently and RPE can be employed as the primary method of intensity regulation. As a person's fitness level rises, RPE can also be used as a basis for modifying his/her exercise prescription (Borg, 1973).

Physiological and Psychological Benefits of Exercise

Exercise is divided into two separate categories one termed aerobic and the other termed anaerobic.

> Aerobic exercise - because it is rhythmic in nature, uses large muscle groups, and elevates heart rate for prolonged periods of time - challenges the cardiovascular system to deliver oxygen to muscles and forces the system to improve. In contrast, anaerobic exercise is done in spurts and thus does not effectively challenge the cardiovascular system (Stamford, 1985, p. 186).

Most competitive sports such as basketball, football, tennis, and racquetball are considered anaerobic sports as they require intense bursts of energy followed by short periods of rest between points and plays when muscles replenish stored energy. The high intensity levels required by anaerobic exercise tend to increase the chance of injury, compared to the risks associated with milder forms of aerobic exercise (Stamford, 1985). Decreased risk of injury and increased challenge to the cardiovascular system has made aerobic exercise the preferred choice of exercise for many individuals; doctors and physiologists alike (Campbell et al., 1986; and Monahan, 1986).

There are many benefits of aerobic exercise presented by the literature. Regularly participating in endurance-type activities such as cross-country skiing, cycling, rowing, rope skipping, running, swimming, and walking has been shown to increase maximal oxygen consumption, decrease percent body fat, decrease heart rate, increase bone density, and develop and maintain higher levels of functional capacity, especially the cardiovascular and respiratory functions (deVries, 1980; Lane, Bloch, Jones, Marshall, Wood, & Fries, 1986; McArdle et al., 1981; Ryan, 1980: and Wilmore, 1977). Other physiological benefits of endurance-type activities are listed in Table 3 (Wilmore, 1977).

Table 3. Physiological changes resulting from endurance conditioning.

Heart
Lower resting heart rate
Lower heart rate during submaximal exercise
Increased heart rate recovery after exercise
Increased stroke volume (blood volume pumped per beat)
Myocardial hypertrophy (increased heart size)
Increased contractility (strength of contraction)
Blood Vessels and Blood Chemistry
Lower resting systolic and diastolic blood pressure
Lower risk of arteriosclerosis (hardening of the arteries)
Lower serum lipids
Greater blood supply to muscles
Greater blood volume
Greater efficiency of oxygen and carbon dioxide exchange in muscles
Lungs
Greater functional capacity during exercise
Greater blood supply
Greater diffusion of respiratory gases
Lower residual volume
Neural, Endocrine and Metabolic Function
Greater glucose tolerance
Greater enzymatic function in muscle cells
Decreased body fat percentage
Less psychological stress
Increased maximal oxygen uptake

> Over the last 30 years more than 40 published studies have looked at the effects of regular physical activity, to learn whether people who are more active have a healthier life than less active or sedentary people. Not all of these studies support the hypothesis that active people are healthier, but most of the studies demonstrate that they do better, particularly in relation to chronic disease. Coronary artery disease is the major disease for which we have evidence that active people are healthier. They have substantially lower mortality rates (Campbell et al., 1986, p. 145).

The exercise intensity required to lower one's risk for many chronic disorders (i.e., coronary artery disease, obesity, osteoporosis, hypertension and cancer) consist of less than about 7.5 kcal/min. Routine every day activities such as walking and stair climbing can contribute the most to lowering the risk of these chronic diseases (Campbell et al., 1986).

Research suggests that postal carriers are protected (have a reduced risk) against cardiovascular disease due to the fact that walking five to ten miles a day is part of their job (Monahan, 1986). The reason for this risk reduction is that aerobic exercise produces several changes that help in the prevention of heart disease, such as reduction of body fat due to the increased number of calories burned, lower serum lipid concentrations, and reduction of high blood pressure (Lampman, Schteingart, & Foss, 1985; and Stamford, 1983). Anything that gives the body less weight to support will restrict the rise of blood pressure during physical activity (Mann, Meyer, Montoye, Paffenbarger, Ryan, & Shphard, 1979). A study by Dressendorfer, Smith, Amsterdam, and Mason (1982) demonstrated that increased maximal oxygen consumption ($\dot{V}O_{2max}$) in cardiac patients reduced heart rate and systolic blood pressures during submaximal exercise. This reflected a reduction in myocardial oxygen demand, allowing subjects to obtain higher workloads before reaching their ischemic threshold. Aside from helping cardiac patients, aerobic exercise has also been reported to help Type II diabetes mellitus patients by improving insulin-mediated glucose utilization and increasing peripheral insulin sensitivity (Lampman et al., 1985).

Aerobic exercise improves delivery of oxygen to the muscles due to changes which occur in the blood and heart. Exercise increases blood volume and raises the level of oxygen-carrying hemoglobin in red blood cells (Littell, 1981; and Stamford, 1983). "Synthesis of protein in the heart muscle increases because it is contracting against an increased resistance, and this leads to hypertrophy of the muscle fibers. Consequently, the heart is able to manage a larger stroke volume and a greater maximum cardiac output" (Mann et al., 1979). Guyton (1986) reported a 400 ml/min increase in maximal oxygen consumption when comparing the athletically trained average male to the untrained average male.

Aside from the cardiorespiratory benefits, several studies have also suggested that weight bearing activities such as walking and running may also play a role in slowing down the progression of osteoporosis due to the positive changes that occur in bone density (campbell et al., 1986; and Paffenbarger et al., 1986).

> Other orthopedic changes that occur with exercise include stronger ligaments which bind bones together at joints; stronger tendons, which attach muscles to bone; and thickened cartilage, which helps bones fit together at joints. These changes occur mostly in exercise such as running, in which there is great orthopedic stress, rather than bicycling or swimming, in which the body is supported. Unfortunately the orthopedic changes occur more slowly than the cardiovascular changes, and therefore orthopedic injury can result from doing too much too soon (Stamford, 1983, p. 145).

A very important question asked many researchers is: can exercise prolong ones life? A recent study performed by Paffenbarger et al. (1986) showed death rates of Harvard alumni declined steadily as energy expended by activity increased from less than 500 to 3500 kcal per week. However, exercising beyond 3500 kcal increased death rates slightly. The study by Paffenbarger et al. (1986) suggests that there is a protective effect of exercise against all-cause mortality in all age groups studied, and therefore an indication of additional years of life expectancy.

Along with the physical benefits there are also many psychological benefits reported by individuals participating in regular aerobic exercise. Getchell (1982) states that although there is no hard evidence supporting these benefits, recent studies do indicate that people who exercise regularly feel less tired, more disciplined, more relaxed, more productive at work, more satisfied with their appearance, more self confident, a reduced sense of personal insecurity, and an improved social well being. According to Ebel, Sol, Bailey, & Schecher (1983), exercise has been found to reduce such symptoms as moderate depression, insomnia, excess stomach acidity, restlessness, anxiety, general fatigue and tiredness, and lastly headache and mental tension. Evidence suggests that exercise can improve mental outlook and self-image, reduce tension and anxiety, and increase self-determination (Stamford, 1983; and Stedman, 1985). In a study to determine the effect of exercise on extremely obese subjects the following psychological parameters were noted to improve: somatization, obessive-compulsiveness, depression, anxiety, hostility, reduction in perceived hunger, and elevated moods (Lampman et al., 1985).

> Even if we can't walk away from our problems or worries, we can often walk them off and return feeling bolstered and rejuvenated. Walking has been shown to improve morale, productivity, creativity and intellect. Walking can provide an outlet for pent-up emotions, while ideas fall into place (Brown & Rodgers, 1885, p. 105).

These physiological and psychological benefits coupled with decreasing an individuals percent body fat and increasing cardiovascular fitness has increased awareness of the importance of exercise (i.e., walking and running). Knowing the energy cost of an activity can greatly aid in determining the amount of fat utilized and the level of cardiovascular fitness attained.

Walking and Running Energy Expenditure

Two of the most commonly chosen modes of exercise in the United states today are walking and running (Campbell et al., 1986; and Ryan, 1980). Both modalities are inexpensive, can be performed anywhere, anytime, and by almost anyone. Energy expenditure for both walking and running are dependent on the intensity, duration, and frequency at which each activity is performed. Other factors that affect energy cost are body weight, type of terrain, walking or running form, stride length, stride frequency, and environmental factors such as snow, rain, temperature, or wind (McArdle et al, 1981; and Schultz, 1980).

> Many people believe that if you walk a mile or run a mile you burn the same number of calories. To test that notion, several years ago we reviewed several studies and came up with some guidelines for the gross caloric cost of walking vs running. Our research suggests that walking burns 1.15 kcal per kg of body weight per mile, while running burns 1.7 kcal/kg/mile. A 70-kg man burns about 80 calories in waking a mile and 120 calories in running a mile. So he would have to walk 1.5 miles to get the same caloric expenditure as running 1 mile. Furthermore, unless one walks extremely fast or extremely slowly, the caloric cost per unit of distance is relatively independent of speed (Campbell et al., 1986, p. 150).

"The energy cost of conventional walking and running are equal at a crossover speed of approximately 8 kilometer per hour (4.35 miles per hour); at speeds slower than this walking becomes more efficient while at faster speeds running elicits a lower energy expenditure" (Hagberg & Coyle, 1984, p. 74). McArdle et al. (1981), and Wyndham & Strydom (1971) examine the speed of walking and energy cost from a different perspective. They state that energy cost of walking increases linearly with an increase in speed between 3.0 and 8.0 kilometer per hour (1.86 and 4.35 mph). At speeds greater than 4.35 miles per hour the walking speed to caloric cost relationship becomes curvilinear and therefore less efficient (McArdle et al., 1981).

Running energy cost, on the other hand, remains linear at speeds between 8 and 22 kilometers per hour (5 to 13.7 mph) which means that the total energy cost for running a given distance is the same whether the pace is fast or slow. For example, a person running a mile at a speed of 10 miles per hour burns twice the energy a person running the same mile at 5 miles per hour; however the runner running at 5 miles per hour will take twice as long to complete the mile run (12 minutes compared to the 6 minutes taken by the person running 10 miles per hour). Therefore, the energy expended for the mile will be equal as long as the running speeds stay between 5 to 13.7 miles per hour. From an energy standpoint, it is more economical to discontinue walking and begin jogging or running at speeds greater than 8 kilometers or 5 miles per hour (McArdle et al., 1981).

> In the range of 2 to 4 mph the energy cost per mile and per minute for walking is less than the energy cost for jogging. However, when you get up into the range of 5 mph you're probably burning a similar number of calories, and if you're walking 6 or 7 mph you're actually burning more calories than in a jogging program. Walking is less efficient at these brisk speeds. In some of our studies we're finding that people can walk 5 to 6 mph, but these speeds are very uncomfortable, especially if the person isn't trained in the racewalking technique. So it probably isn't good to tell people to go out and walk 5 mph (Campbell et al., 1986, p. 150).

"Walking and running speed is increased in one of three ways: (1) by increasing the number of steps taken each minute (stride frequency) (2) by increasing the distance between steps (stride length) or (3) by increasing both the length and frequency of strides" (McArdle et al., 1981, p. 122). Even though the third option seems to be the most practical means of increasing speed of walking and running, studies indicate a different view point.

Workman & Armstrong (1963), and Murray, Kory, Clarkson, & Sepic (1966) performed studies on walkers to determine the main factor regulating walking speed. Both concluded that due to the fact that walking requires the back foot to remain on the ground until the front foot makes contact, stride length becomes an ineffective means of increasing walking speed. Therefore stride frequency is the major precursor for increasing walking speed. Because of the continuous contact rule in walking, an increased correspondence of trunk and arm musculature is required to move the leg rapidly forward. This explains why, at speeds greater than 8 kilometers per hour, it is more economical to run than walk (McArdle et al., 1981).

Unlike walking, running is not restricted by the continuous ground contact rule. In running, there is a point at which both feet leave the ground simultaneously. This is important in that it enables the runner to more easily increase the length of stride. The increased stride length is the primary way to increase running speed up to 23 kilometers per hour (14.3 miles per hour). At speeds greater than 14.3 miles per hour, stride length has usually reached its maximum efficiency and stride frequency begins to appear as the dominant factor in increasing running speed. If one continues to increase his/her stride length by overstriding, a decrease in efficiency will develop. Generally, it is more costly to overstride than understride. Usually the most economical stride length for a particular running speed is the one selected by the runner himself/herself. Lengthening the stride above the normal selected stride only produces a greater increase in oxygen consumption and ultimately wastes energy (McArdle et al., 1981).

Although the speed of walking and running is an important factor determining the energy cost for these two modalities body weight also contributes considerably to increased energy expenditure. Research shows that as body weight increases, energy expenditure for walking and running activities rises proportionally (McArdle et al., 1981; Workman & Armstrong, 1963; and Yanker, 1983). The estimated caloric (kcal) values for both walking and running, relative to speed and body weight can be seen in Tables 4 and 5 (Yanker, 1983; and McArdle et al., 1981).

Table 4. Net energy expenditure (kcals) per hour for horizontal walking.

Walking Speed in mph	Weight in Pounds 100	120	140	160	180	200	220
2.0	130	160	185	210	240	265	290
2.5	155	185	220	250	280	310	345
3.0	180	215	250	285	325	360	395
3.5	205	248	290	330	375	415	455
4.0	235	280	325	375	420	470	515
4.5	310	370	435	495	550	620	680
5.0	385	460	540	615	690	770	845

Note: The information in Table 4 was taken from Yanker, 1983, p. 103.

Table 5. Net energy expenditure (kcals) per hour for horizontal running.

Running Speed in mph	Weight in Pounds 100	119	137	163	181	199	225
4.97	400	432	496	592	656	720	816
5.60	450	486	558	666	738	810	918
6.20	500	540	620	740	820	900	1020
6.84	550	594	682	814	902	990	1122
7.46	600	648	744	888	984	1080	1224
8.08	650	702	806	962	1066	1170	1326
8.70	700	756	868	1036	1148	1260	1428
9.32	750	810	930	1110	1230	1350	1530
9.94	800	864	992	1184	1312	1440	1632

Note: The information in Table 5 was taken from McArdle et al., 1981, p. 122.

In order to eliminate the body weight factor energy expenditure can be expressed in terms of oxygen uptake ($\dot{V}O_2$) ($ml \cdot kg^{-1} \cdot min^{-1}$) or better yet METs (3.5 $ml \cdot kg^{-1} \cdot min^{-1}$). Because energy requirements in the MET equation are expressed in relation to individual body weight in kilograms, the differences for body weight between heavier and lighter men, or when comparing men and women, is essentially eliminated. This elimination of the body weight factor allows for the generalization of the energy cost of an activity for an entire population. It also makes it easier to prescribe exercise intensity levels for a variety of individuals. Table 6 shows the predicted MET values for horizontal walking and running at various speeds (ACSM, 1980, pp. 17-19).

Table 6. Approximate energy requirements in METs for horizontal walking and running.

Walking		Running	
Speed in mph	MET Levels	Speed in mph	MET Levels
1.7	2.3	4.0	7.1
2.0	2.5	5.0	8.6
2.5	2.9	6.0	10.2
2.0	3.3	7.0	11.7
3.4	3.6	7.5	12.5
3.75	3.9	8.0	13.3
4.0	4.1	9.0	14.8
5.0	4.8	10.0	16.3

Over the past few years researchers have been interested in ways to increase the energy expenditure of walking as they believe running produces a greater risk of injury, Yanker (1983, pp. 20-21) states why many feel this way:

> In jogging the feet come into contact with the ground along a straight line below the center of the body, causing an abnormal change of motion in the knee joint. The angular stresses on the jogger's knee joints cause a condition called runner's knee, a type of bursitis that accounts for approximately 25 percent of injuries. The impact of each jogging step on the body's shock-absorption system is 3.5 to 4 times a person's weight, while the shock impact of the walking step is only 1.5 times body weight. This is a significant difference for preserving the body's musculoskeletal and internal organs from injury.
>
> Walking develops better balanced leg muscles on both the front and the back of the leg. Muscular development in joggers' and skaters' legs is uneven. Overdeveloping some leg muscles while leaving others in a relatively weaker state results in the stronger muscles overpowering the weaker ones, causing them to be strained to the point of inflammation and even rupture. "Shin splints," or injured muscles in the front and lower leg, is a condition that results from overdeveloped calf muscles, which overpower the muscles at the front of the lower leg.

Some of the suggestions researchers have given to increase energy expenditure of walking without increasing impact consist of hill walking, weighted walking, and race walking. Campbell et al. (1986) suggested hill walking as a possibility but found increased loads and rates of loading on the forefoot, lead to excessive pronation and possible injury. Weighted walking, using hand, body, or ankle weights to increase the intensity of walking was also examined. Again, increased injury rates to the shoulders, elbows, upper back muscles, along with magnified stress to the legs and knees proved to be a major deterrent (Campbell et al., 1986; and Stamford, 1984). According to Campbell et al. (1986, p. 148) "research results have suggested that vigorous arm movement alone, without the use of hand held weights, may increase the energy cost of walking between 0.5 and 1.0 MET (1 MET = 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ of oxygen uptake)". However, so far no research has been done in this area. The closest association would be the research performed on race walking. Hagberg & Coyle (1984) state that many physiologists have looked at and have mixed feelings about whether competitive race walkers, by adopting their specialized biomechanical techniques, are able to alter the usual efficiency relationship examined between running and walking. The data reported by Hagberg & Coyle (1984 & 1983) indicate that race walkers have not changed the crossover speed for $\dot{V}O_2$. In their study, race walkers demonstrated that race walking and running still become equally efficient between 8 and 9 kilometers per hour which is very similar to the 8 kilometers per hour crossover speed found previously for conventional walking and running. Although Hagberg & Coyle (1983 & 1984) demonstrated that the efficiency level of race walking stayed the same as conventional walking they also found that race walkers were able to achieve the same maximal oxygen uptakes as runners.

Speedwalking

Speedwalking is an easy-to-learn combination of foot, leg, hip, and arm movements adapted and modified from the old sport of race walking (Rowen & Laiken, 1980). Basically speedwalking is walking with added vigorous arm movements, and is almost as easy to perform. If one can walk he or she should be able to speedwalk (Rowen & Laiken, 1980).

Rowen & Laiken (1980) designed speedwalking after Rowen injured his knee while jogging. Rowen stated that ordinary walking was too slow and did not give him the psychological boost that running did, thus he developed speedwalking.

Because speedwalking is rhythmic in nature, uses large muscle groups, and elevates the heart rate for prolonged periods of time it is considered an aerobic exercise (Stamford, 1985). Being an endurance type activity speedwalking can also provide the same physical benefits as other aerobic exercises (i.e., increase maximal oxygen consumption, decrease percent body fat, decrease heart rate, increase bone density, develop and maintain higher levels of functional capacity, and decrease the possibility of cardiovascular disease, diabetes, and osteoporosis. Because speedwalking is a weight bearing activity it also stimulates all the orthopedic changes seen with running and walking and if maintained throughout ones life may increase longevity). Aside from all the physical benefits, speedwalking also promotes the psychological benefits of exercise (e.i., reduced moderate depression, insomnia, excess stomach acidity, restlessness, anxiety, general fatigue and tiredness, mental tension and headaches, along with improving mental outlook, self-image, increased self-determination, and control in ones life).

Like walking, speedwalking is easily accessible and easily regulated. Because ones feet never leave the ground in speedwalking it too possesses less potential for injury than more stress producing exercises such as running or aerobics (Brown & Rodgers, 1985; and Rowen & Laiken, 1980). The joint movements in speedwalking are also very similar to those of normal walking and thus reduce chance of injury and promote better development of balanced leg muscles in the front and back of the leg (Yanker, 1983). Speedwalking requires limited equipment (walking shoes, exercise shorts, and shirt) and can be done conveniently anywhere and anytime. Also, speedwalking is a companionable activity. One can participate in speedwalking with others and enjoy their company (Campbell et al., 1986; and Rowen & Laiken, 1980).

The most significant disadvantage claimed for walking according to Porcari et al. (1986) is that normal fast walking may not be of sufficient intensity to produce aerobic fitness benefits in males under 50 years of age. Walking is also time consuming as one has to walk 1.5 miles in order to obtain the same caloric expenditure as running 1 mile (Campbell et al., 1986). One can increase energy expenditure (intensity) of walking in one of three ways: (1) increase the weight one carries such as with hand or ankle weights (2) increase the percent of grade one walks on such as hill walking or (3) increase stride frequency such as in race walking (McArdle et al., 1981; and Workman & Armstrong, 1963). Speedwalking uses an increased arm movement to keep in synchronization with the legs and increase the stride frequency. This increased stride frequency along with the increased muscle mass used to perform the vigorous arm movements increases the intensity level (oxygen uptake) of speedwalking while still allowing for a comfortable and low stress exercise (McArdle et al., 1981; and Rowen & Laiken, 1980).

Speedwalking as defined by Rowen & Laiken (1980) is a rhythmic and natural walking motion that is patterned after race walking. Unlike race walking, speedwalking is performed with less exaggerated hip and arm movements, making it easier for individuals to perform the exercise.

The following technique is performed when speedwalking: (1) an exaggerated heel toe movement with the heel planted on the ground at a 90 degree angle to the shin (2) a forceful contraction of the quadriceps and hip flexors to lock the knee and propel the body over the straightened leg (3) slight increase in hip and arm movements and (4) arms bent slightly at the elbow between 45 and 90 degrees (Rowen & Laiken, 1980). In order to simplify speedwalking even more and due to the increased possibility for injury, the straight leg action was eliminated in this study. Instead a new form of speedwalking was implemented. A bent knee action at the point of heel contact and throughout the driving motion was used. The leg, in bent knee speedwalking, remains in a slightly bent position similar to that of regular walking. Just prior to the lift off phase, the leg straightens, in preparation for the push off. Other than the 90 degree heel angle, increased hip and arm movements, increased step frequency, and the greater bend in the elbow which produces nearly a right angle arm carry, speedwalking and walking exhibit much similarity. The main difference supposedly lies in an increased intensity level that speedwalking is expected to exhibit. Since speedwalking is a relatively new exercise, there has yet to be any studies investigating the energy cost and cardiovascular responses of the activity.

By examining the literature investigating walking, running, and race walking, one might assume speedwalking to follow similar patterns. Because no one has performed research in the area of energy cost or on the intensity level of speedwalking, this assumption is in need of further investigation. It is also difficult to determine appropriate frequency, duration, and intensity levels for individuals, without knowing the energy cost of the exercise being prescribed. For individuals searching for an exercise to expend more calories without greatly increasing risk of injury, speedwalking may just be the alternative exercise mode they have been looking for.

Summary

The measurement of energy expenditure has fascinated scientists since the 1800's. Through indirect methods of measuring oxygen consumption, scientists and physiologists together have been able to accurately predict the energy costs of specific activities. Taking into account the energy cost of an activity, and carefully following the ACSM (1986) guidelines regarding intensity, duration, frequency, rate of progression, and type of activity, safe and effective exercise prescriptions can be developed for most individuals. In recent years, walking and running have become two of the most popular exercise modes used by Americans to improve their fitness levels. Other forms of exercise are also beginning to show comparative fitness potentials. One such exercise is Speedwalking. Knowledge of the energy cost for this uncomplicated form of walking would provide a base from which physiologists could safely and effectively write exercise prescriptions and introduce speedwalking as an exercise alternative for running and its less intense counterpart walking.

CHAPTER III

METHODS AND PROCEDURES

The primary question to be answered by this study was: what is the energy cost of horizontal speedwalking in males, 20 to 40 years of age? A sub-question was: what is the differences between speedwalking and running at four and five miles per hour? A second sub-question was: can a sufficient intensity level be elicited by speedwalking to produce aerobic fitness benefits in males under 50 years of age? The above two subquestions relate to the two hypotheses presented in this thesis

In this chapter, the methods used in collection and analysis of the data are described. The chapter is divided into the following five sections: research design, subjects, organization of the data collection, data collection procedures, and statistical treatment of the data.

Research Design

A descriptive, quasi-experimental research design was used in this study. Measurements of heart rate, and oxygen consumption were made on a group of moderately-to highly-trained men. Each subject performed four submaximal tests. The four tests were randomly assigned, consisting of:

1) 4.0 miles per hour speedwalking

2) 5.0 miles per hour speedwalking

3) 4.0 miles per hour running

4) 5.0 miles per hour running

All four tests were performed at zero percent grade for six minutes or until three minutes of steady-state exercise was achieved. Steady-state for this study was defined as less than a 150 ml difference in oxygen uptake for three consecutive minutes (Cigala, 1985).

The values recorded in the last three minutes of each exercise test were averaged and assumed to represent the steady state values for each test. Oxygen uptake in $ml \cdot kg^{-1} \cdot min^{-1}$ was converted to METs to calculate the energy expenditures for each of the four exercise levels. The averaged heart rate, oxygen uptake, and rated perceived exertion values for both speedwalking and running were compared using a dependent t-test to determine any significant differences. Finally, averaged steady-state heart rates and MET values recorded for each subject were divided by each subject's maximal values to determine the percentage of maximal effort.

Subjects

The subjects selected for study were 43 males 20 to 39 years old, 37 of whom completed all the testing. Four subjects ran into time commitment problems. One subject's data was eliminated due to an inaccurate maximum oxygen consumption test and another subject exhibited an abnormal stress test, prohibiting him from continuing in the study.

This study thus included 37 moderately-to highly-trained males between 20 and 40 years of age. Subject selection was based on regular involvement in endurance exercise as determined by interview. The requirement for a minimum activity level was set at two miles or 20 minutes of endurance exercise, three times per week.

All subjects voluntarily participated in the study and gave their written informed consent (Appendix A). Subjects were screened for any medical condition that might contraindicate participation in vigorous exercise by using the information obtained on the Self-administered Pre-exercise Medical History Form (Appendix B). Subjects were also required to perform a symptom limited graded exercise test. A twelve lead electrocardiogram and a Beckman metabolic cart were used to collect data on maximum heart rates and oxygen uptake values. Anyone with an abnormal test or not obtaining a nine MET level minimum were prohibited from continuing in the study.

Information concerning current activity levels and training background was obtained from a Self-administered Pre-exercise Medical History Form (Appendix B). All subjects were nonathletes: most were runners, cyclists or played basketball. One subject was a trained cyclist. Subjects exercised an average of 90 minutes 3.6 times a week. Ninty-five percent of the subjects reported being involved in high school athletics while only thirty-five percent reported being involved in college athletics.

The physical characteristics of the subjects are presented in Table 7.

Table 7. Physical characteristics of the subjects.

Variable	Mean	SD	Range
Age (yrs)	29.0	6.15	20 - 39
Height (cm)	178.3	5.67	160.60 - 187.20
Height (in)	70.2	2.23	63.25 - 73.75
Weight (kg)	76.1	9.93	57.18 - 101.36
Weight (lbs)	167.9	21.91	126.08 - 223.50

Organization and Data Collection

A pilot study was performed to determine the exact training and testing procedures to be used in this study. Five college aged subjects, three males and two females, participated in a three hour speedwalk training session. During this session, it was found that straight leg speedwalking was both difficult to perform and placed a great amount of hyperextension stress on the back of the knee. For these reasons, it was decided that bent-leg speedwalking would be the preferred technique in this study. It was also concluded that the training would take place on the treadmill as opposed to training on level ground due to a difference in force producing factors.

One male subject performed the graded exercise test and the four required submaximal tests to eliminate any testing problems which may have been overlooked. The only changes made were an increased warm-up period, and a longer test period (six minutes instead of five minutes).

All data for this study was collected in a 5-week period between the months of May and June, 1986. The testing schedule is shown in table 8.

Table 8. Testing schedule.

Week	Test	Test condition
1	Introductory Speedwalking Meeting -informed consent -self-administered pre-exercise medical history form -sign up for symptom limited graded exercise test and training week	-
2	Symptom Limited Graded Exercise Test	No strenuous exercise the day of the test 3-hour fast
3	Training Program	-
4-5	Four submaximal tests - 4.0 mph speedwalk - 5.0 mph speedwalk - 4.0 mph running - 5.0 mph running	No strenuous exercise the day of the test 3-hour fast

In the initial speedwalking meeting, an explanation of the purpose of the study, testing procedures and time required for testing was explained to the subjects. Informed consent and the self-administered pre-exercise medical history forms were completed. A symptom-limited graded exercise test (SL-GXT) was demonstrated for all subjects to observe. At the end of the demonstration each subject practiced walking and running on a motor-driven treadmill. Lastly, subjects were scheduled for a SL-GXT and a training time. Each subject also received an instruction sheet (Appendix C) and speedwalking training program handout (Appendix D).

All subjects were required to participate in the one week training program to acquaint themselves with the bent-leg speedwalking technique. Training sessions took place on Monday, Wednesday, and Friday for one hour each day. All training took place on the treadmills in the La Crosse Human Performance Lab. The first day of the training program began with a video tape demonstration of speedwalking. The tester then demonstrated (with subject participation) the correct heel toe strike, thigh technique, hip swivel, head, neck, and torso position, arm movements, and bent leg speedwalking. An explanation of straight leg speedwalking by Rowen and Laiken (1980, pp. 40-58) was given to each subject for a basic reference. At the end of the demonstration everyone practiced speedwalking at 4.0 miles per hour on one of three treadmills. The instructor video taped each subject on the main pit treadmill and made corrections or suggestions. At the end of the hour the video was played back so that each subject could view themselves speedwalking and ask any questions. The second day began with each subject practicing speedwalking on the treadmills, at 5.0 miles per hour. Each subject was again video taped speedwalking on the main treadmill. The video tape was played for each subject at the end of the period and suggestions and comments were given. On the last day of the training program the subjects observed a student perform a four mile per hour speedwalking test. At the end of the demonstration each subject signed up for two separate test sessions convenient for them, within the succeeding two weeks. Each subject was required to participate in the two experimental sessions in order to complete the required four exercises. The order of the exercises was randomly drawn by each subject prior to the first exercise session. Subjects performed two exercises per session. The exercises were as follows:

1) 4.0 mph speedwalking
2) 5.0 mph speedwalking
3) 4.0 mph running
4) 5.0 mph running

Data Collection Procedures

Body Height

The subjects height was measured using a Continental Health-O-Meter (No. 400DKL) with the subject wearing exercise clothes and shoes, standing erect and hands at side. The sliding ruler was placed on the top of the subjects head and height was read to the nearest quarter inch. Three separate height measurements were taken on each subject, once before the symptom limited graded exercise test and again before each of the two test sessions. Mean height was calculated by taking the average of the three heights recorded.

Body Weight

The subjects weight was also measured on a Continental Health-O-Meter (No. 400DKL) with the subject standing, wearing exercise clothes (shorts and shirt) and shoes. weight was recorded to the nearest quarter pound. Three separate weight measurements were taken on each subject. Once before the symptom-limited graded exercise test (SL-GXT) and again before each of the two test sessions. Mean weight was calculated by taking the average of the three weights recorded.

Heart Rates

Heart rates and electrocardiograph (ECG) recordings for the symptom limited graded exercise test were recorded on four different ECG recorders, due to mechanical problems. The four ECG recorders used were as follows: Burdick (M 200), Burdick (M 350), Marquette Case II, and the Marquette Series 2000.

Medi-Trace Offset disposable electrodes were used for obtaining a twelve-lead ECG. For a diagram of the electrode placement see (Appendix E). A gauze pad saturated with alcohol and a small square brillo pad, made by the Marquette Company was used to clean and abrade the skin. Once the electrodes were in place the resistance level was checked with an ohm meter. A reading of 1500 ohms was required or the electrode was removed and the skin prepared again and another electrode put in place. Heart rates were taken from the ECG monitor every minute with a hard copy twelve lead ECG printed out at the end of each three minute stage. The highest heart rate obtained during the test was considered and recorded as the maximal heart rate.

Heart rate for submaximal speedwalking and running tests were determined on the Burdick (M 200) Electrocardiographic (ECG) Recorder using a modified three lead system (CM5). The subjects were prepped with the alcohol gauze pad and brillo pad and had three electrodes (Medi-Trace Offset disposable) placed on their chests. For a visual diagram of the (CM5) lead system see (Appendix F). Lead wires were then attached to the electrodes and connected to the ECG recorder as the subject was seated on the treadmill. Heart rates were recorded in the last 15 seconds of every minute. The number of R-complexes in the 15 second strip were then counted and multiplied by four to achieve a heart rate value.

Metabolic Measurements

The Beckman Metabolic Measurement Cart (BMMC) was used to determine oxygen uptake along with other respiratory gas values for both the symptom limited graded exercise test and the submaximal speedwalking and running tests. An adjustable headpiece supporting a Hans Rudolf nonrebreathing valve (model 2700) and mouthpiece were fitted on the subjects. The valve was connected to the BMMC via plastic tubing which was secured to a pole with a rubber velcro strap. The pole was attached to the treadmill handrail and helped to support the weight of the tubing. A picture of the set up is shown in (Appendix G). Before each test session the temperature and barometric pressure were adjusted according to a thermometer in the BMMC and a barometer in the testing laboratory. The volume calibration of the BMMC was performed by injecting air into the mixing chamber of the BMMC from a 3 liter pump. Three full pumps were injected into the BMMC, and the volume meter was adjusted until 9 liters of air registered on the volume meter. Prior to every test the bell was removed from the mixing chamber of the BMMC so that the CO_2 analyzer could be adjusted with room air to a 0.05 percentage reading. The bell remained off and the BMMC was then calibrated by using a known gas sample which had been previously verified by the Micro-Scholander technique. The BMMC was calibrated to within .01 for both oxygen and carbon dioxide percentages. Oxygen consumption was recorded each minute of every test. Subjects had to finish at least 30 seconds of the minute in order for recordings to be considered accurate. The highest maximal oxygen consumption recorded for more than 30 seconds was considered the maximum oxygen uptake ($\dot{V}O_2$).

<u>Symptom Limited Graded Exercise Test</u>

In order to continue participation in the study, all 37 subjects were required to perform a SL-GXT which entailed maximal oxygen uptake measurements ($\dot{V}O_{2max}$). The Bruce protocol was used for testing purposes. Subjects were able to observe the testing protocol during the introductory week. The SL-GXT was performed as a precaution to be sure subjects had no physical problems that might cause any one of them harm when performing the four submaximal tests. The $\dot{V}O_{2max}$ data was also collected at this time in order to formulate each subjects true maximal oxygen uptake. A percentage of maximal oxygen uptake was determined for the lower intensity speedwalking and running exercises.

After height and weight measurements were recorded the subject was prepped for a twelve lead ECG. Resting supine, standing, and 20 second hyperventilation twelve lead ECGs were recorded along with heart rates and blood pressures. After reviewing the history and baseline data for abnormalities the subject was allowed to be tested. The testing procedure began with a brief description of the test and the Borg ratings of Perceived Exertion scale (RPE). Instructions on mounting the treadmill were given to each subject and any questions were answered. The BMMC headpiece and breathing apparatus were fitted to the subject and a nose clip placed over the nose. The subject was asked to straddle the treadmill and the treadmill turned on. A description of the treadmill calibration procedure is given in (Appendix H). A Bruce protocol shown in Table 9 was used for each subject.

Table 9. Bruce treadmill protocol.

STAGE	DURATION	SPEED MPH	ELEVATION (% GRADE)	METS
1	3 min.	1.7	10%	4.65
2	3 min.	2.5	12%	7.05
3	3 min.	3.4	14%	10.17
4	3 min.	4.2	16%	13.49
5	3 min.	5.0	18%	17.25
6	3 min.	5.5	20%	24.60
7	3 min.	6.0	22%	28.40

Four testers were present for each test. Time was kept by a digital stop watch and placed so all personnel could see it. Blood pressures were recorded at one and three minutes of each level with approximately 30 seconds notice given to the ECG tester. Heart rates were also recorded every one and three minutes. A twelve lead ECG was recorded at the end of each three minute stage, at maximal exertion, and immediate post, along with blood pressure and heart rate. Ratings of perceived exertions (RPEs) were recorded at the end of each stage.

Prior to changing an exercise level, the subject was instructed that there would be a change in speed and elevation. Each participant was asked to communicate with a thumbs down hand signal when he was within 30 seconds of his max so that the required blood pressure, and twelve lead ECG could be recorded and the treadmill brought down to 1.5 miles per hour, 0% grade. Blood pressures, heart rates and twelve lead ECGs were recorded every two minutes during cool down. Cool down lasted approximately 6 to 8 minutes. The headpiece and breathing valve were removed during cool down. The test was terminated when heart rates and blood pressures were within normal resting levels. Note: four tests were performed under a physician's supervision due to age and/or family history. Examples of the two data recording forms used for the SL-GXT can be seen in (Appendix I).

<u>Submaximal Speedwalking and Running Tests</u>

Upon entering the human performance lab each subject randomly selected the order in which the tests would be performed. Each subject signed up for two test sessions at which he performed two tests per session. The four tests were as follows:

1) 4.0 mph speedwalking
2) 5.0 mph speedwalking
3) 4.0 mph running
4) 5.0 mph running

After collecting height and weight measurements, the subject was prepped with the aid of an alcohol gauze pad and brillo pad. Three electrodes were then placed in a CM5 lead arrangement on the subject's chest. Once prepped, the subject was connected to the ECG recorder and a description of the Borg ratings of perceived exertion scale was read to him. See (Appendix J) for a description of the Borg ratings of perceived exertion scale read to the subjects. Any questions were also answered at this time. After all questions were answered the headpiece and breathing apparatus were fitted to the subject's head and the subject asked to be seated in a chair placed on the treadmill. The test was started when the subject was seated and comfortable. The subject rested for five minutes while seated on the treadmill. Resting heart rates and respiratory gas values were obtained for each minute during the rest and exercise periods. Heart rates were calculated by recording a 15 second ECG strip at the end of each rest and exercise minute. The number of R-complexes in a 15 second period were then counted and multiplied by four to determine minute heart rate values. The respiratory gas values of minute ventilation $\dot{V}_E$ ($ml \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), and respiratory exchange ratio (RER) were calculated by the BMMC each minute. The first exercise test began after the five minute rest period. The subject was reminded which randomly determined exercise he was to perform while straddling the treadmill belt. The chair was removed and the treadmill started. The subject began warming up by walking at 2.0 miles per hour, 5% grade for the first two minutes, followed by 3.0 miles per hour, 10% grade for the next two minutes. At the end of the four minute warm up the treadmill was brought down to 0% grade and the speed was increased in relation to the test being performed. The subject then progressed into the exercise indicated by the experimenter. Each subject continued to perform the exercise for at least six minutes in order to establish steady-state. If steady-state was not attained within six minutes the test was extended until oxygen consumption varied no more than 150 milliliters for three consecutive minutes. Each minute, heart rate, respiratory gas values, and ratings of perceived exertion were obtained and recorded. The subject was asked to assess his perceived exertion on the Borg scale. A chart of the scale was held so that the subject could see and point to the number which best represented his exertion level. The experimenter announced the number to confirm the subject's selection.

Once three minutes of steady-state values were recorded, the treadmill was slowed down to 2.0 mph or lower until the subject's heart rate came down to 70% of his attained maximal heart rate. The treadmill was then stopped and the subject was seated on the treadmill and the breathing apparatus was removed. The subject rested for at least five minutes until his/her heart rate returned to baseline. The baseline heart rate was determined to be within ten beats (or lower) of the average heart rate response obtained during the rest period prior to the exercise. If the subject did not achieve base line heart rate within five minutes, the rest period was extended.

At the end of the rest period, the subject was asked to perform another exercise. The breathing apparatus was again fitted to the subject and the test procedure stated above was repeated starting with the straddling of the treadmill. This procedure was followed for all four tests. An example of the data recording form used for the submaximal tests can be found in (Appendix K).

Statistical Treatment of the Data

Basic descriptive statistics (means, standard deviations, and ranges), were calculated for age, height, weight, and steady-state variables of heart rate, $\dot{V}_E$ ($ml \cdot min^{-1}$), $\dot{V}O_2$ ($l \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), RER, ratings of perceived exertion, and MET levels. Heart rate and respiratory gas values were determined by averaging the values obtained during the last three minutes of the steady-state period. The oxygen consumption values were converted to METs. A dependent t-test was used to compare the physiological values obtained by the subjects speedwalking at four and five miles per hour with the physiological values achieved running at four and five miles per hour. The heart rates and MET levels obtained by the subjects for each of the four tests were used to calculate a percentage of the maximum heart rates and MET levels achieved in the symptom limited graded exercise test. A test of proportions was performed to determine if 80% of the subjects were able to achieve 65% of their maximal heart rate or 50% of their maximal MET level. To determine the relationship between heart rate and ratings of perceived exertion, a Pearson product-moment correlation coefficient was computed. A 0.05 level of significance was established for all statistical tests.

CHAPTER IV

RESULTS AND DISCUSSION

The primary question to be answered in this study was: what is the energy cost of horizontal speedwalking in males 20 to 40 years of age? A sub-question was: what are the differences between speedwalking and running at four and five miles per hour? A second sub-question was: can a sufficient intensity level be elicited by speedwalking to produce aerobic fitness benefits in males under 50 years of age? The above two sub-questions relate to the two hypotheses stated in this thesis.

This chapter presents the results of the study and a discussion of the following topics: physical characteristics, physiological characteristics, energy cost of horizontal speedwalking and running, speedwalking intensity levels, speedwalking and running physiological differences, and ratings of perceived exertion (RPE).

Results

Physical Characteristics

Thirty-seven moderately-to highly-trained males performed a maximal oxygen uptake ($\dot{V}O_{2max}$) test and four submaximal oxygen uptake tests consisting of:

1) 4.0 mph speedwalking

2) 4.0 mph running

3) 5.0 mph speedwalking

4) 5.0 mph running

None of the subjects in this study were practicing speedwalkers. All subjects were taught the speedwalking technique. Table 7 (page 44) shows the descriptive characteristics of the subjects in this study. The mean age for the group was 29 years of age with a range of 20 to 39 years of age. Mean height for the subjects was 178.3 centimeters or 70.2 inches. Mean weight recorded for the individuals in this study was 76.1 kilograms or 167.9 pounds.

Physiological Characteristics

Mean respiratory gas values of minute ventilation ($\dot{V}_E$, $ml \cdot min^{-1}$), oxygen uptake ($\dot{V}O_2$, $L \cdot min^{-1}$ and $\dot{V}O_2$, $ml \cdot kg^{-1} \cdot min^{-1}$), and respiratory exchange ratio (RER) for each test are reported in Table 10. Also recorded in Table 10 are the average MET values, heart rates, and ratings of perceived exertion (RPE) levels of the subjects.

At 4.0 mph, subjects attained a higher heart rate and MET value in running versus speedwalking. Running elicited a mean heart rate of 125 beats per minute (bpm) and a MET value of 7.6 compared to speedwalking which showed a heart rate of 112 bpm and a MET value of 5.8 at 4.0 mph. The subjects also perceived (RPE) running to be more difficult than speedwalking at 4.0 mph, expressing an RPE value of 11 for running as apposed to an RPE value of 10 for speedwalking. At 5.0 mph the reverse occurred, subjects attained a higher heart rate and MET value in speedwalking (147 bpm heart rate and a 9.3 MET value) as opposed to running (137 bpm heart rate and a 8.9 MET value). They also perceived speedwalking as slightly more demanding than running at 5.0 mph, reporting an RPE value of 14 for speedwalking compared to an RPE value of 12 for running.

Table 10. Physiological characteristics.

Variable	$\dot{V}_E$ (ml·min^{-1})	$\dot{V}O_2$ (L·min^{-1})	$\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	METs	HR (bts·min^{-1})	RER	RPE
Maximal							
Mean	132,339.0	4.09	54.2	15.5	188	1.10	17.0
SD	21,339.0	.65	9.1	2.5	8	0.09	1.8
Range							
Low	80,678.0	2.11	32.8	9.4	171	0.96	13.0
High	178,230.0	5.25	74.9	21.4	203	1.46	20.0
<u>4.0 mph</u>							
Speedwalk							
Mean	37,994.0	1.54	20.2	5.8	112	0.84	10.0
SD	6,605.0	.24	2.0	.6	15	0.04	2.0
Range							
Low	21,231.0	0.91	13.7	3.9	86	0.77	6.0
High	56,633.0	2.08	25.2	7.2	145	0.92	16.0
Run							
Mean	49,660.0	2.03	26.7	7.6	125	0.87	11.0
SD	7,066.0	.27	2.3	.7	14	0.05	2.4
Range							
Low	36,966.0	1.32	22.1	6.3	92	0.81	8.0
High	69,551.0	2.69	31.1	8.9	158	0.98	17.0
<u>5.0 mph</u>							
Speedwalk							
Mean	67,812.0	2.48	32.6	9.3	147	0.93	14.0
SD	14,557.0	.38	3.1	.9	20	0.07	2.6
Range							
Low	50,138.0	1.86	24.9	7.1	108	0.83	9.0
High	106,673.0	3.28	39.1	11.2	181	1.17	20.0
Run							
Mean	58,218.0	2.38	31.2	8.9	137	0.87	12.0
SD	9,231.0	.33	2.7	.8	16	0.04	2.4
Range							
Low	41,024.0	1.57	23.7	6.8	99	0.81	17.0
High	84,222.0	3.12	37.2	10.6	167	0.95	18.0

Energy Cost

The calculated energy cost of horizontal speedwalking and running at four and five miles per hour obtained in this study are listed in Table 11. Subjects speedwalking at 4.0 mph elicited lower energy costs (5.8 METs and 4.47.8 kcals) than running at 4.0 mph (7.6 METs and 594.7 kcals). To be more exact, 1.8 METs and 146.9 kcals more were used by the subjects running than speedwalking, indicating that speedwalking is more efficient (burns less calories) than running at 4.0 mph. In contrast subjects speedwalking at 5.0 mph elicited higher energy costs (9.3 METs and 737.6 kcals) than running at 5.0 mph (8.9 METs and 697.0 kcals). Therefore, 0.4 METs and 40.6 kcals less were used by subjects running than speedwalking, indicating that speedwalking is less efficient (burns more calories) than running at 5.0mph.

Table 11. Calculated energy cost of horizontal speedwalking and running at four and five miles per hour.

Variable	$\dot{V}O_2$ ($L \cdot min^{-1}$)	RER	kcal ($kcal \cdot L^{-1} \cdot min^{-1}$)	kcal ($kcal \cdot min^{-1}$)	kcal ($kcal \cdot hr^{-1}$)	METs
4.0 mph						
Speedwalk	1.539	0.84	4.850	7.464	447.8	5.8
Run	2.028	0.87	4.887	9.911	594.7	7.6
5.0 mph						
Speedwalk	2.478	0.93	4.961	12.293	737.6	9.3
Run	2.377	0.87	4.887	11.616	697.0	8.9

Speedwalking Intensity Levels

The intensity levels achieved by the subjects speedwalking in this study are reported in Tables 12 and 13. Heart rate, MET levels, and ratings of perceived exertion (RPE) are the three most common measurements used in determining intensity (ACSM, 1986). The American College of Sports Medicine (1986) states that in order for an individual to gain aerobic benefits from a specific exercise he/she must maintain an intensity level above 65% of his/her maximal heart rate or 50% of his/her maximal oxygen uptake ($\dot{V}O_{2max}$ or functional capacity).

Speedwalking at 4.0 mph did not show a significant number of subjects reaching 65% of their maximum heart rate or 50% of their maximum MET level. As a matter of fact, only 18.9% of the subjects obtained 65% of their maximal heart rate and only one individual obtained a sufficient intensity, 56.19% of his maximal MET level. Running at 4.0 mph, on the other hand, demonstrated 51.4% of the subjects reaching 65% of their maximal heart rate and 35.1% of the subjects reaching 50% of their maximal MET level.

At 5.0 mph speedwalking, 86.5% of the subjects obtained 65% of their maximal heart rate and 78.4% of the subjects were able to achieve 50% of their maximal MET level. Running at 5.0 mph on the other hand demonstrated 83.8% of the subjects reaching both 65% of their maximal heart rate and 50% of their maximal MET level. Tables 12 and 13 show the percentage of maximal heart rate and MET levels achieved in this study and the accumulative percentage and number of subjects who obtained those percentages. For a more detailed table of individual accumulative percentages see Appendixes L and M.

Table 12. Accumulative percentage of subjects reaching maximal heart rates.

% of Max HR	4.0 mph speedwalk %	4.0 mph speedwalk F	4.0 mph run %	4.0 mph run F	5.0 mph speedwalk %	5.0 mph speedwalk F	5.0 mph run %	5.0 mph run F
90%	0.0	0	0.0	0	10.8	5	0.0	0
85%	0.0	0	0.02	1	27.0	6	5.4	3
80%	0.0	0	2.7	1	40.5	5	16.2	4
75%	0.0	0	8.1	2	64.9	9	29.7	5
70%	10.8	5	18.9	4	70.3	2	59.5	11
* 65%	18.9	3	51.4	12	86.5	6	83.8	9
60%	35.1	6	83.8	12	97.3	4	94.6	4
55%	70.3	13	94.6	4	-	-	97.3	1
50%	89.2	7	97.3	1	-	-	-	-
45%	97.3	3	-	-	-	-	-	-

% = accumulative percentage of subjects F = frequency
* = ACSM (1986) training heart rate level

Table 13. Accumulative percentage of subjects reaching maximal MET values.

% of Max HR	4.0 mph speedwalk %	F	4.0 mph run %	F	5.0 mph speedwalk %	F	5.0 mph run %	F
90%	0.0	0	0.0	0	0.0	0	0.0	0
85%	0.0	0	0.0	0	0.0	0	0.0	1
80%	0.0	0	0.0	0	5.4	3	2.7	1
75%	0.0	0	0.0	0	13.5	3	8.1	2
70%	0.0	0	0.0	1	24.3	4	18.9	4
65%	0.0	0	8.1	3	40.5	6	21.6	1
60%	0.0	0	18.9	4	45.9	2	32.4	4
55%	0.02	1	24.3	2	56.8	4	32.4	0
* 50%	0.02	0	35.1	4	78.4	8	83.8	19
45%	21.6	8	64.9	11	91.1	5	86.5	1
40%	32.4	4	86.5	8	97.3	2	94.6	3
35%	56.8	9	97.3	4	-	-	97.3	1
30%	91.1	13	-	-	-	-	-	-
25%	94.6	1	-	-	-	-	-	-
20%	97.3	1	-	-	-	-	-	-

% = accumulative percentage of subjects F = frequency
* = ACSM (1986) training MET level

It is important to note, that in this study heart rate and MET values showed only a .53 correlation at 5.0 mph of speedwalking. Lower correlations (r = .26 and .28) were found for 4.0 mph speedwalking and running. Running at 5.0 mph was the only test that did not produce a significant correlation between heart rate and MET values. Table 15 shows the correlation values (r) between heart rate and MET measurements for each test, as well as, the correlation of heart rate of one test with the MET level of another test.

Table 14. Heart rate and MET value correlations.

		4.0 mph		5.0 mph	
		Speedwalk HR	Run HR	Speedwalk HR	Run HR
4.0 mph					
Speedwalk METs	r	.2668 -----	.2384	*.2985	.2312
Run METs	r	.0714	*.2824 -----	.0542	.1641
5.0 mph					
Speedwalk METs	r	*.4589	*.4342	*.5307 -----	*.4030
Run METs	r	-.0015	.1773	.0456	.1336 -----

* = $p < 0.05$ r = correlation
---- = the correlation between heart rate and MET values with the same test

Speedwalking and Running Physiological Differences

A t-test was performed to determine the differences between speedwalking and running. Table 15 shows the physiological data recorded for speedwalking and running in this study.

Table 15. Physiological comparison of speedwalking and running at 4.0 and 5.0 miles per hour.

Variable	Mean Difference	SD	Standard Error	t-Value	2-Tail Probability
		4.0 mph Speedwalk and Run			
$\dot{V}_E$ ($ml \cdot min^{-1}$)	-	4778.59	785.60	-14.85	0.000*
$\dot{V}O_2$ ($ml \cdot min^{-1}$)	-489.14	173.73	28.56	-17.13	0.000*
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	-6.48	2.48	0.41	-15.88	0.000*
RER	-0.03	0.04	0.01	-4.27	0.000*
HR ($bts \cdot min^{-1}$)	-13.60	8.15	1.34	-10.14	0.000*
RPE	-0.24	1.96	0.32	-0.75	0.456
METs	-1.85	0.71	0.12	-15.94	0.000*
		5.0 mph Speedwalk and Run			
$\dot{V}_E$ ($ml \cdot min^{-1}$)	9593.76	9549.59	1569.94	6.11	0.000*
$\dot{V}O_2$ ($ml \cdot min^{-1}$)	101.00	228.77	37.61	2.69	0.011*
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	1.31	3.23	0.53	2.47	0.018*
RER	0.06	0.05	0.01	7.56	0.000*
HR ($bts \cdot min^{-1}$)	9.54	8.49	1.39	6.84	0.000*
RPE	2.35	2.34	0.38	6.12	0.000*
METs	0.37	0.91	0.15	2.45	0.019*

* = $p < 0.05$ df = 36

All physiological measures ($\dot{V}_E$, $\dot{V}O_2$, RER, HR, and METs) except for ratings of perceived exertion (RPE) showed a significant difference between speedwalking and running at 4.0 mph. It appears, from Table 15, that subjects had difficulty rating the level of perceived exertion between speedwalking and running at this lower speed.

At 5.0 mph on the other hand, speedwalking and running showed a significant difference in all physiological measures. Subjects seemed to have no difficulty determining RPEs at this speed. Subjects did indicate, however, that speedwalking was more difficult than running at 5.0 mph.

Ratings of Perceived Exertion (RPE)

According to ACSM (1986), Borg (1973), and Skinner et al. (1973) the Ratings of Perceived Exertion (RPE) scale correlates highly with cardiorespiratory and metabolic variables such as $\dot{V}O_2$, heart rate, ventilation, and blood lactate in normal, healthy individuals. To determine the extent to which RPE actually did correlate with measured physiological variables during speedwalking and running a Pearson product momment-correlation coefficient was computed. The results are shown in Table 16.

Ratings of perceived exertion correlated significantly with $\dot{V}O_2$, METs, $\dot{V}_E$ and heart rates recorded during speedwalking at 5.0 mph. Both running speeds produced significant correlations between RPE and $\dot{V}_E$ and heart rate, but no significant correlations were found with $\dot{V}O_2$ or METs. Speedwalking at 4.0 which was lowest in intensity level, showed no correlations between RPE and the other variables. Maximum RPE values were not recorded as the data collected, proved inaccurate, due to the fact that RPE values were only recorded every third minute during the subjects symptom limited graded exercise test and true maximum numbers were not always attained.

Table 16. Ratings of perceived exertion correlations.

		$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	METs	$\dot{V}_E$ ($L \cdot min^{-1}$)	HR ($bts \cdot min^{-1}$)
4.0 mph Speedwalk RPE	r	.0675	.0620	.1557	.2002
Run RPE	r	-.0159	-.0101	*.3422	*.3453
5.0 mph Speedwalk RPE	r	*.3628	*.3705	*.5798	*.4609
Run RPE	r	.1515	.1622	*.3310	*.3374

* = $p < 0.05$ r = correlation

Discussion

Physical Characteristics

The subjects in this study were reported to have a mean age of 29 years of age with a range between 20 to 39 years of age, a mean height of 70.2 inches and a mean weight of 167.9 pounds. These physical characteristics are comparable to those reported by the Hanes Survey of 1980, which stated the average United States male between the age of 25 to 34, depicted a mean height of 70 inches and a mean weight of 179 pounds (Hamilton & Whitney, 1982). Thus the subjects in this study were 11 pounds lighter than the subjects in the Hanes Survey, suggesting the subjects in this study to be slightly below average in the weight category. The difference in the age spread and fitness level of the subjects tested may have had some effect on the lower than average weight factor.

Physiological Characteristics

Guyton (1986) examined the maximal oxygen uptake levels ($\dot{V}O_{2max}$) of males and came up with the following approximate values:

Untrained average male	3600 ml/min
Athletically trained average male	4000 ml/min

The mean oxygen uptake levels ($\dot{V}O_{2max}$) for the subjects in this study was calculated to be 4090 ml/min, placing them in the category of Guyton's athletically trained average male.

The ACSM (1986) equation for determining age predicted maximal heart rates (220 minus one's age) indicates that the subjects in this study should have achieved a maximal heart rate of about 191 bpm (220 minus the mean age 29). ACSM (1986) safely states though that the range of maximal heart rates at any age is large, even for apparently healthy adults and that estimates of age predicted maximal heart rates should only be used as a guide for test termination. The mean maximal heart rate recorded in this study was 188 bpm, only 3 bpm lower than the ACSM age predicted maximal heart rate indicating that subjects did achieve maximal efforts. Other indicators that subjects obtained true maximal values is that the mean respiratory quotient in this study was well over 1.0 (1.10) and a leveling off or drop in oxygen consumption was seen with each subject (Taylor, Buskirk, & Henschel, 1955).

The lower mean heart rate and MET level recorded for speedwalking compared to running at 4.0 mph, and the higher mean heart rate and MET level obtained speedwalking compared to running at 5.0 mph project the same crossover pattern as discussed in the energy cost section below. The lower heart rate and MET level recorded for speedwalking at 4.0 mph and the higher heart rate and MET level recorded for speedwalking at 5.0 mph indicate that speedwalking is easier than running at 4.0 mph, were as running is easier than speedwalking at 5.0 mph.

Energy Cost

The energy cost of speedwalking and running reported in this study indicated that speedwalking at 4.0 mph elicited a lower energy expenditure (5.8 METs or 447.8 kcals) than running at 4.0 mph (7.6 METs or 594.7 kcals). At 5.0 mph speedwalking demonstrated a higher energy expenditure (9.3 METs or 737.6 kcals) than running at 5.0 mph (8.9 METs or 697.0 kcals). These lower energy costs elicited at 4.0 mph and higher energy costs elicited at 5.0 mph demonstrated by speedwalking when compared to running at the equivalent speeds, follow the same crossover pattern reported by ACSM (1986), Hagberg & Coyle (1984), McArdle et al. (1981), Wyndham & Strydom (1971), and Wyndham, Strydom, Van Graan, Van Rensburg, Rogers, Greyson, & Van Der Walt (1971), who all found that conventional walking and running appeared to be equal in energy cost at a speed of approximately 8 kilometers per hour (4.35

mph). It is apparent from these investigations and from the present study that at speeds slower than 4.35 mph, walking and speedwalking both remain more efficient than running. But at speeds faster than 4.35 mph, running elicits a lower energy expenditure. This change in efficiency below and above 4.35 mph can be explained biomechanicaly. Below 4.35 mph the amplitude of the vertical excursion becomes the important factor (Murray et al., 1966). In walking and speedwalking the feet never leave the ground and the body is propelled forward in a linear fashion. In running the double-support period of walking and speedwalking is replaced by a period in which both feet leave the ground simultaneously. This produces a bouncing motion and in turn makes running less efficient at slower speeds. At higher speeds stride length becomes the critical component. Unlike walking and speedwalking, running is not restricted by the continuous ground contact rule. In running, the point at which both feet leave the ground enables the runner to easily increase stride length and therefore makes running more efficient at speeds above 4.35 mph (Yanker, 1983). Another reason running becomes more efficient above 4.35 mph is that there is an increased correspondence of trunk and arm musculature required to move the leg rapidly forward in both walking and speedwalking (McArdle et al., 1981). For individuals looking for an exercise to expend more calories, speedwalking or walking at 5.0 mph may be a viable exercise mode.

Comparing the MET values for running at 4.0 mph with those calculated by ACSM (1986) at 4.0 mph, only a small .5 MET difference is seen (7.6 METs in the study compared to 7.1 METs calculated by ACSM). A .30 difference is seen at 5.0 mph running (8.9 METs compared to 8.6 METs noted by ACSM). The small variance in MET levels when comparing ACSM running values with this study's values for running, indicates some degree of credibility and accuracy in MET measurements obtained in this study.

Examining the comparison between speedwalking and regular walking, a difference of 1.7 METs is seen at 4.0 mph (5.8 METs speedwalking compared to 4.1 METs calculated by ACSM walking). At 5.0 mph a difference of 4.5 METs is seen (9.3 METs speedwalking compared to 4.8 METs walking). Campbell et al., (1986) reported that walking with vigorous arm movements alone without the use of hand held weights raised the MET value of walking by only 0.5 to 1.0 MET. In this study speedwalking elicited a 1.7 MET increase over walking at 4.0 mph and a 4.5 MET increase over walking at 5.0 mph.

Since kilocalories ($kcal \cdot hr^{-1}$) per hour is another unit by which to measure energy expended by an activity, results similar to those reported for the MET values were expected and did appear. Higher kcal values were recorded for speedwalking than normal walking and likewise, higher values were recorded when comparing the kcal values found for running in this study, with those calculated in past studies.

McArdle et al. (1981) estimated running at both speeds to expend less Kcals than those calculated in this study. At 4.0 mph running, 594.7 Kcals per hour were calculated compared to 491 Kcals per hour found by McArdle et al. (1981). A difference of 103.7 Kcals per hour. At 5.0 mph running, 697 Kcals per hour were achieved compared to 614

Kcals per hour found by McArdle et al. (1981). A difference of 83 Kcals per hour.

The Kcals per hour estimated by Yanker (1983) for a 168 pound individual walking 4.0 and 5.0 mph presents a lower kcal expenditure than that calculated for speedwalking in this study. Speedwalking at 4.0 mph expended 447.8 Kcals per hour compared to 387.0 Kcals per hour calculated by Yanker. A difference of 60.8 Kcals per hour. Speedwalking at 5.0 mph expended 737.6 Kcals per hour compared to 627.0 Kcals per hour calculated by Yanker. A difference of 110.6 Kcals per hour. The increased caloric expenditure that speedwalking elicites over normal walking is most likely due to the increased arm movement, stride frequency, and overall increase in muscle mass required by the individual speedwalking (McArdel et al., 1981; and Rowen & Laiken, 1980). Also as speed of gait increases in speedwalking, the range of motion in the hips, knees, and ankles also increase and thereby expend more energy (Murray et al., 1966).

Since the MET values for running at four and five miles per hour in this study are close to those calculated by ACSM (1986), there is good reason to believe that the values found for speedwalking are also accurate. The large variance in kcal values for running in this study may be do to the extrapolation process used to estimated kcal values from a table of running kcal values reported by McArdle et al. (1981). Running kcal values had to be extrapolated due to the fact that few kcal values have been recorded and published for running below 5.0 mph. The MET and kcal values recorded in this study for speedwalking indicates that speedwalking does in fact expend more energy than regular walking, making speedwalking an excellent choice as a weight loss exercise and providing greater aerobic benefits than that of walking. The increased energy cost elicited by speedwalking at 5.0 mph is more than likely attributable to the increased muscle demand required by the increased arm movement used in speedwalking to keep in synchronization and allow for an increased stride frequency (McArdle et al., 1981; and Rowen & Laiken, 1980).

Speedwalking Intensity Levels

Porcari, Kline, Hintermeister, Freedson, Ward, Gurry, McCarron, & Rippe (1986); and Yanker (1983) stated that normal fast walking may not be of sufficient intensity to produce fitness benefits in males under 50 years of age. The data presented in Tables 12 and 13 (pages 61 and 62) demonstrates that although normal walking may not produce a sufficient intensity level, speedwalking at 5.0 mph and above did produce an intensity level able to provide fitness benefits. Of the subjects tested speedwalking at 5.0 mph, 86.5% were able to achieve 65% of their maximal heart rate and 78.4% were able to achieve 50% of their maximal MET level.

The null hypothesis in this study stated that 80% of the subjects tested speedwalking in this study would not obtain sufficient intensity levels (65% of their maximum heart rates and/or 50% of their maximal oxygen consumption values) to produce aerobic benefits. This hypothesis can be rejected at 5.0 mph speedwalking but must be accepted at 4.0 mph speedwalking.

The low correlation between heart rate and MET values in this study place some skepticism on whether or not both heart rate and MET values should be used together for exercise prescription. One of these two values (heart rate or MET values) may be more accurate and safer to use, in prescribing exercise for individuals, than the other. Why the low correlations were obtained between mean heart rate and MET levels for speedwalking at 4.0 and 5.0 mph, and running at 4.0 mph is unclear. It was expected that since both heart rate and MET levels supposably rise at similar rates with increased work intensity that they would correlate better (Astrand & Saltin, 1961). Equally confusing is the fact that no significant correlations appeared between the mean heart rate and MET level recorded for running at 5.0 mph.

Speedwalking and Running physiological differences

Comparing the physiological measurements of $\dot{V}_E$, $\dot{V}O_2$, RER, HR, and METs of speedwalking with running at 4.0 mph and at 5.0 mph produced significant differences in all measurements except RPE at 4.0 mph. Therefore, it is assumed that at 4.0 mph and 5.0 mph, speedwalking and running do not produce similar physiological effects. In contrast, they actually produce the opposite effects. This can most likely be explained biomechanically by measured efficiency. Below 4.35 mph amplitude of the virtical excursion is greater in running than in speedwalking making speedwalking more efficient. Above 4.35 mph the stride length is restricted in speedwalking due to the continuous ground contact rule but is not restricted in running as the runner can easily increase stride length during the period when both feet leave the ground. Therefore, running becomes the more efficent exercise mode at speeds above 4.35 mph. The null hypothesis in this study states that there would be no significant difference in oxygen consumption between speedwalking or running at four and five miles per hour. From the imformation collected in this thesis, this hypothesis can be rejected.

Since all physiological measurements but RPE at 4.0 mph showed significant differences between speedwalking and running, we began to question whether or not the subjects ability to honestly determine rates of work at lower intensities may be impaired. One reason ratings of perceived exertion may not have shown significant difference at 4.0 mph is that neither speedwalking or running pose much difficulty at such a low speed. Subjects therefore had difficulty judging which was harder at 4.0 mph.

Ratings of Perceived Exertion (RPE)

Unlike the reports given by Borg (1973), and Skinner et al. (1973) the RPE ratings given by the subjects in this study did not correlate highly with the metabolic variables $\dot{V}O_2$, METs, $\dot{V}_E$, and HR. Borg (1973) stated that his 15 point ratings scale supposably correlated highly (r = .80 to .90) with heart rate in healthy people varying from light to heavy work. The highest significant correlation between RPE and heart rate in this study was listed for speedwalking at 5.0 mph and was only (r = .46). This low RPE to heart rate correlation along with the low correlations reported with the other metabolic variables tends to decrea-e the credibility of the RPE scale. The only reasonable explanation for the lower RPE correlations found in this study is presented by Butts (1982) who stated that RPE responses in middle range of work intensity are a more accurate reflection of heart rate than those recorded at the extremes. The subjects RPE ratings in this study did demonstrate a higher degree of accuracy as the intensity level increased but not until an average of 7.6 METs and a heart rate of 125 bts/min were obtained running at 4.0 mph. No significant correlations between RPE and the other variables were produced for speedwalking at 4.0 mph. Thus, using RPE as an intensity indicator with lower intensity exercise may be questionable as far as safety is concerned. However, the data supports that RPE appears to be accurate with higher intensity exercise.

Summary

Subjects in this study had a mean age of 29 years of age with a range between 20 to 39 years of age. Being slightly trained athletes they exhibit a lower (11 pounds) than average body weight. Subjects elicited a lower energy cost for speedwalking as apposed to running at 4.0 mph and a higher energy cost for speedwalking as apposed to running at 5.0 mph. Speedwalking also demonstrated a similar crossover speed with running (4.35 mph) as that recorded for walking and running by ACSM (1986), Hagberg & Coyle (1984), McArdle et al. (1981), Wyndham & Strydom (1971), and Wyndham et al. (1971). The mean energy cost for speedwalking at 4.0 mph was calculated to be 5.8 METs or 447.8 kcals per hour. The mean energy cost for speedwalking at 5.0 mph was calculated to be 9.3 METs or 737.6 kcals per hour. Speedwalking evoked a 1.7 MET or 60.8 kcal per hour increase over walking at 4.0 mph and a 4.5 MET or

110.6 kcal per hour increase over walking at 5.0 mph, proving that speedwalking does, in fact, expend more energy than walking at both speeds. This increased energy cost of speedwalking over normal walking is also consistent with the increased intensity level subjects were able to achieve speedwalking at 5.0 mph. Of the subjects tested speedwalking at 5.0 mph, 86.5% were able to reach 65% of their maximal heart rates and 78.4% were able to attain 50% of their maximal MET values, indicating that subjects under 50 years of age can achieve sufficient intensity levels to produce aerobic fitness benefits speedwalking 5.0 mph or faster. The low correlations between heart rate and MET levels, and the low correlations reported for RPE and metabolic variables $\dot{V}O_2$, METs, $\dot{V}_E$, and HR lends some skepticism as to which measurement or combination of measurements (heart rate, MET levels, or RPE) is/are the most accurate determinants of exercise intensity.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The primary question to be answered by this study was: what is the energy cost of horizontal speedwalking in males, 20 to 40 years of age? A sub-question was: what are the differences between speedwalking and running at four and five miles per hour? A second sub-question was: can a sufficient intensity level be elicited by speedwalking to produce aerobic fitness benefits in males under 50 years of age? The above two sub-questions relate to the two hypotheses presented in this thesis.

Thirty-seven moderately-to highly-trained males participated in this study. Each subject performed a series of five tests, including a symptom-limited graded exercise test and four randomly ordered submaximal tests consisting of the following:

1) 4.0 mph speedwalking

2) 4.0 mph running

3) 5.0 mph speedwalking

4) 5.0 mph running

The following physiological parameters were determined for each test: heart rate (HR), rate of perceived exertion (RPE), metabolic measurements of oxygen uptake $\dot{V}O_2$ $(ml \cdot min^{-1})$, $\dot{V}O_2$ $(ml \cdot kg^{-1} \cdot min^{-1})$, metabolic equivalents (METs), respiratory gas values of minute ventilation $\dot{V}_E$ $(ml \cdot min^{-1})$, and respiratory exchange ratio (RER).

For complete physiological profile, physical data including age, height, and weight were also collected.

None of the subjects in this study were practicing speedwalkers. Therefore, all participants were taught the speedwalking technique during a one-week training program. The training week consisted of three one-hour sessions at which time the subjects were videotaped while practicing the speedwalking technique on motor-driven treadmills. Speedwalking problems were reviewed on tape and suggestions were given, corrections made, and the subjects revideoed.

Statistical analysis of the data included basic descriptive statistics (means, standard deviations, and ranges) calculated for physiological and physical data. A Pearson product-moment correlation coefficient was computed to obtain correlation coefficients between all measurements. A dependent t-test was performed to examine the relationship between speedwalking and running at four and five miles per hour. A test of proportions was performed to determine if 80% of the subjects were able to achieve aerobic benefits from speedwalking at four and five miles per hour. Significance was established at the 0.05 level of confidence for all statistical tests.

Results

Based on the statistical analyses of the data, the following results were obtained:

1. The energy cost of speedwalking at 4.0 mph was 5.8 METs or 447.8 kilocalories per hour.

2. The energy cost of speedwalking at 5.0 mph was 9.3 METs or 737.6 kilocalories per hour.
3. The energy cost of running at 4.0 mph was 7.6 METs or 594.7 kilocalories per hour.
4. The energy cost of running at 5.0 mph was 8.9 METs or 697.0 kilocalories per hour.
5. Speedwalking evoked a 1.7 MET or 60.8 kilocalorie per hour increase over values calculated by ACSM (1986) and Yanker (1983) for conventional walking at 4.0 mph, and a 4.5 MET or 110.6 kilocalorie per hour increase over values calculated by ACSM (1986) and Yanker (1983) for conventional walking at 5.0 mph.
6. Of the subjects tested speedwalking at 4.0 mph 18.9% obtained 65% of their maximal heart rate and only one individual obtained 50% of his maximal MET level.
7. Of the subjects tested speedwalking at 5.0 mph 86.5% obtained 65% of their maximal heart rate and 78.4% of the subjects obtained 50% of their maximal MET level.
8. Running at 4.0 mph demonstrated 51.4% of the subjects reaching 65% of their maximal heart rate and 35.1% of the subjects acquired 50% of their maximal MET level.
9. Running at 5.0 mph demonstrated 83.8% of the subjects reaching both 65% of their maximal heart rate and 50% of their maximal MET level.

10. Mean heart rate and MET values showed the following correlations for each of the four tests performed:

4.0 mph speedwalking	r = .2668*
4.0 mph running	r = .2824*
5.0 mph speedwalking	r = .5307*
5.0 mph running	r = .1336

* = ($p < 0.05$)

11. Comparing the physiological measurements of $\dot{V}_E$, $\dot{V}O_2$, RER, HR, RPE, and METs of speedwalking with running at 4.0 mph and at 5.0 mph produced significant differences in all of the measurements except RPE at 4.0 mph.

12. Ratings of perceived exertion (RPE) given by the subjects in this study did not correlate highly with the metabolic variables $\dot{V}O_2$, $\dot{V}_E$, METs, and HR.

13. Some of the subjects in this study did complain of soreness in the anterior portion of the tibia (shin splints), posterior portion of the knee, and in the groin, quadriceps, hamstring, and Gracilis muscles.

Conclusions

Based on the results obtained in this study, the following conclusions are offered:

1. The null hypothesis which stated there would be no significant difference in oxygen consumption between speedwalking or running at four and five miles per hour was rejected.

2. The null hypothesis which stated eighty percent of the subjects tested would not obtain sufficient intensity levels to produce aerobic benefits (65% of their maximum heart rates and/or 50% of their maximal oxygen consumption values) was accecpted for 4.0 mph speedwalking but rejected for 5.0 mph speedwalking.
3. Speedwalking and running exhibit the same crossover pattern as conventional walking and running, that is, speedwalking and running still become equally efficient around 8 kilometers per hour (4.35 mph).
4. Below 4.35 miles per hour (4.0 mph) speedwalking is more efficient (less physically demanding) than running.
5. Above 4.35 miles per hour (5.0 mph) speedwalking becomes less efficient (more physically demanding) than running.
6. Speedwalking expends more energy than conventional walking at either 4.0 mph or 5.0 mph.
7. The increased energy cost elicited by speedwalking is more than likely attributable to the increased muscle mass required by the increased arm and trunk movement used in speedwalking to keep in synchronization and allow for an increased stride frequency.
8. Speedwalking at 4.0 mph will not produce a sufficient intensity level to produce aerobic fitness benefits in males under 50 years of age and who have a maximal oxygen uptake ($\dot{V}O_2$) level close to 4000 ml/min or a maximal MET level near 15.5 METs.

9. Speedwalking at 5.0 mph will produce a sufficient intensity level to produce aerobic fitness benefits in males under 50 years of age and who have a maximal oxygen uptake ($\dot{V}O_2$) level close to 4000 ml/min or a maximal MET level near 15.5 METs.

10. The MET, kcal, and intensity values recorded in this study prove speedwalking to be an excellent exercise alternative (e.g., walking or running) with the ability to provide aerobic benefits in males under 50 years of age.

11. Speedwalking significantly differs from running in all physiological measurements $\dot{V}_E$, $\dot{V}O_2$, RER, HR, and METs.

12. In this group of physically active subjects the ratings of perceived exertion (RPE) scale does not correlate as highly with the metabolic variables oxygen uptake ($\dot{V}O_2$), heart rate, ventilation ($\dot{V}_E$), and METs.

13. The low correlations between heart rate and MET levels, and the low correlations reported for RPE and metabolic variables $\dot{V}O_2$, $\dot{V}_E$, METs, and HR lends some skepticism as to which measurement or combination of measurements (heart rate, MET level, or RPE) is the most accurate to determine exercise intensity.

Recommendations

Based on the results and conclusions of this study and the pilot study the following recommendations are offered:

1. In order to lower the risk of hyperextending and/or injuring the knee in speedwalking, the knee should not be placed in a locked out position when heel contact is made, rather it should be slightly bent just as in normal walking. For further instructions on how to speedwalk see Appendix N.
2. When prescribing speedwalking for an individual, it may be wise to actually test the person speedwalking on the treadmill.
3. Speedwalking on level ground has somewhat of a different feel than speedwalking on a treadmill. Therefore, speedwalking practice on the treadmill should precede testing.
4. Further investigations to measure energy cost of speedwalking at other speeds and/or with a change in population (i.e., females or cardiac patients) should be pursued.
5. A study examining the biomechanical effects of speedwalking would also be helpful in assessing how safe the exercise truly is.
6. A study that looks at speedwalking verses walking at various speeds would also be helpful.
7. Looking at how well MET levels and heart rates correlate would be beneficial, as many believe the values reported by ACSM to be correct. This study has placed a question mark in that area since the correlations reported were not as high as one would have thought.

8. Re-examining how well Borg's Rating of Perceived Exertion scale correlates with the metabolic variables of $\dot{V}O_2$, $\dot{V}_E$, METs, and HR at various work intensity levels (i.e., maximal, middle, and low intensities) needs to be pursued.

9. There is a need to determine how well new ratings of perceived exertion scales predict exertion levels and how well people respond to these new scales.

10. Speedwalking should be looked at as a possible exercise alternative for healthy, at risk, and patients with cardiovascular, pulmonary, or metabolic diseases.

REFERENCES CITED

American College of Sports Medicine. (1980). Guidelines for graded exercise testing and exercise prescription (2nd ed.). Philadelphia: Lea & Febiger.

American College of Sports Medicine. (1986). Guidelines for exercise testing and prescription (3rd ed.). Philadelphia: Lea & Febiger.

Astrand, P-O. (1976). Aerobic and anaerobic work capacity. Medicine Sport, 9, 55-60.

Astrand, P-O., & Saltin, B. (1961). Oxygen uptake during the first minutes of heavy muscular exercise. Journal of Applied Physiology, 16, 971-976.

Borg, G. A. V. (1973). Perceived exertion: A note on "history" and methods. Medicine and Science in Sports, 5(2), 90-93.

Borg, G. A. V. (1982). Psychological basis of percieved exertion. Medicine and Science in Sports and Exercise, 14(5), 377-381.

Brown, M., & Rodgers, B. (1985). Low-stress fitness. Tucson, AZ: The Body Press.

Butts, N. K. (1982). Physiological profiles of high school female cross country runners. Research Quarterly for Exercise and Sport, 53(1), 8-14.

Cairns, M. (1985). Racewalking: A fitness alternative. Journal of Physical Education, Recreation, and Dance, 3, 50-51.

Campbell, K. R., Franklin, B. A., Freedson, P., Haskell, W. L., Rippe, J. M., & Ward, A. (1986). Walking for fitness: A round table. The Physician and Sportsmedicine, 14(10), 144-159.

Cigala, K. E. Jr. (1985). The energy cost of walking with and without hand weights while performing rythmic hand movements. Unpublished master's thesis, University of Wisconsin-La Crosse, La Crosse, WI.

deVries, H. A. (1980). Physiology of exercise (3rd ed.). Dubuque, IA: Wm. C. Brown Company Publishers.

Dressendorfer, R. H., Smith, J. L., Amsterdam, E. A., & Mason, D. T. (1982). Reduction of submaximal exercise myocardial oxygen demand post-walk training program in coronary patients due to improved physical work efficiency. TUhe American Heart Journal, 103(3), 358-362.

Ebel, H., Sol, N., Bailey, D., & Schechter, S. (Eds.). (1983). Presidential sports award fitness manual. Havertown, PA: FitCom Corporation.

Fox, E. L., & Mathews, D. K. (1981). The physiological basis of physical education and athletics (3rd ed.). Philadelphia: Saunders College Publishing.

Franklin, B. A., Pamatmat, A., Johnson, S., Scherf, J., Mitchell, M., & Rubenfire, M. (1983). Metabolic cost of extremely slow walking in cardiac patients: Implications for exercise testing and training. Archives of Physical Medicine and Rehabilitation, 64(11), 564-565.

Getchell, B. (1982). Being fit: A personal guide. New York: John Wiley & Sons, Inc.

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

Hagberg, J. M., & Coyle, E. F. (1983). Physiological determinants of endurance performance as studied in competitive racewalkers. Medicine and Science in Sports and Exercise, 15(4), 287-289.

Hagberg, J. M., & Coyle, E. F. (1984). Physiologic comparison of competitive racewalking and running. International Journal of Sports Medicine, 5, 74-77.

Hamilton, E. M. N., & Whitney, E. N. (1982). Nutrition: Concepts and controversies (2nd ed.). St. Paul: West Publishing Company.

Harvey, P. (1986, September 4). Learning to walk. Chippewa Herald Telegram, p. 2.

International Committee for the Standardization of Physical Fitness Tests (ICSPFT). (1974). Fitness, health and work capacity: International standards for assessment. New York: Macmillian Publishing Company, Inc.

Jones, D. (1986, September 21). Good health, good living. The Milwaukee Journal Magazine: Wisconsin, pp. 10-36.

Katch, F. I., & McArdle, W. D. (1977). Nutrition weight control, and exercise. Boston: Houghton Mifflin Company.

Kitchen, B. (1981). Race-walking! Runner's World, 16(9), 55-59.

Lampman, R. M., Schteingart, D. E., & Foss, M. L. (1986). Exercise as a partial therapy for the extremely obese. Medicine and Science in Sports and Exercise, 18(1), 19-24.

Lane, N. E., Bloch, D. A., Jones, H. H., Marshall, W. H., Wood, P. D., & Fries, J. F. (1986). Long distance running, bone density, and osteoarthritis. Journal of American Medical Association, 255(9), 1147-1151.

Littell, E. H. (1981). Support responses of the cardiovascular system to exercise. Physical Therapy, 16, 1260-1264.

Mann, G. V., Meyer, B., Montoye, H., Paffenbarger, R., Ryan, A. J., & Shephard, R. J. (1979). A round table for CMI credit: Exercise and the Cardiovascular System. The Physician and Sportsmedicine, 7(9), 55-71.

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

Monahan, T. (1986). From activity to eternity. The Physician and Sportsmedicine, 14(6), 156-164.

Morgan, W. P. (1973). Psychological factors influencing perceived exertion. Medicine and Science in Sports, 5(2), 97-103.

Morris, A. F. (1984). Energy: Equating expenditure in different activities, Running and Fitness, 16, 8-9.

Murray, M. P., Kory, R. C., Clarkson, L. P. T., & Sepic, S. B. (1966). Comparison of free and fast speed walking patterns of normal men. American Journal of Physical Medicine, 45(1), 10-24.

Norris, T. (1986, September 21). Pump till you slump? The Milwaukee Journal Magazine: Wisconsin, p. 21.

Noble, B. J., Metz, K. F., Pandolf, K. B., Bell, C. W., Cafarelli, E., & Sime, W. E. (1973). Perceived exertion during walking and running - II. Medicine and Science in Sports, 5(2), 116-120.

Paffenbarger, R. S., Hyde, R. T., Wing, A. L., & Hsieh, C. C. (1986). Physical activity, all-cause mortality and longevity of college alumni. New England Journal of Medicine, 314(10), 605-613.

Porcari, J., Kline, G., Hintermeister, R., Freedson, P., (FACSM), Ward, A., Gurry, M., Ross, J., McCarron, R., Rippe, J. (1986). Is fast walking an adequate aerobic training stimulus? Medicine and Science in Sports and Exercise, 18(2), Supplement, s81.

Rogers, C. C. (1986). Upper body exercise: Jarming instead of jogging. The Physician and Sportsmedicine, 14(5), 181-186.

Rowen, L., and Laiken, D. S. (1980). The exercise alternative: Speedwalking. New York: G. P. Putnam's Sons.

Ryan, A. J. (1980). The physician and sportsmedicine guide to running. New York: McGraw-Hill Book Company.

Scheen, A., Juchmes, J., & Cession-Fossion, A. (1981). Critical analysis of the "anaerobic threshold" during exercise at constant workloads. European Journal of Applied Physiology, 46, 367-377.

Schultz, P. (1980). Walking for fitness: Slow but sure. The Physician and Sportsmedicine, 8(9), 24-27.

Skinner, J. S., Hutsler, R., Bergsteinova, V., & Buskirk, E. R. (1973). Perception of effort during different types of exercise and under different environmental conditions. Medicine and Science in Sports, 5(2), 110-115.

Stainsby, W. N., & Barclay, J. K. (1970). Exercise metabolism: O_2 deficit, steady level O_2 uptake and O_2 uptake for recovery. Medicine and Science in Sports, 2(4), 177-181.

Stamford, B. (1983). The results of aerobic exercise. The Physician and Sportsmedicine, 11(9), 145.

Stamford, B. (1984). Exercising with hand and ankle weights. The Physician and Sportsmedicine, 12(12), 139.

Stamford, B. (1985). What about anaerobic exercise? The Physician and Sportsmedicine, 13(9), 186.

Stedman, N. (1985). Is exercise overrated? Health, 17, 23-61.

Taylor, H. L., Buskirk, E., & Henschel, A. (1955). Maximal oxygen uptake as an objective measure of audio-respiratory perfomance. Journal of Applied Physiology, 8, 73-80.

Turbin, J. (1984). Walking yes! Jogging no! Olympic Review, 201/2, 526-529.

Wasserman, K., & Whipp, B. J. (1975). State of the art: Exercise physiology in health and disease. American Review of Respiratory Disease, 112, 219-249.

Wasserman, K., Van Kessel, A. L., & Burton, G. G. (1967). Interaction of physiological mechanisms during exercise. Journal of Applied Physiology, 22(1), 71-85.

Wilmore, J. H. (1977). Athletic training and physical fitness. Boston: Allyn & Bacon, Inc.

Wilmore, J. H. (1984). The assessment of and variation in aerobic power in world class athletes as related to specific sports. The American Journal of Sports Medicine, 12(2), 120-127.

Wilmore, J. H., Davis, J. A., & Norton, A. C. (1976). Spedial Communications an automated system for assessing metabolic and respriratory funtion during exercise. Journal of Applied Physiology, 40(4), 619-624.

Wipp, B. J., & Wasserman, K. (1972). Oxygen uptake kinetics for various intensities of constant-load work. Journal of Applied Physiology, 33(3), 351-356.

Workman, J. M., & Armstrong, B. W. (1963). Oxygen cost of treadmill walking. Journal of Applied Physiology, 18(4), 798-803.

Wyndham, C. H., & Strydom, N. B. (1971, May). Mechanical efficiency of a champion walker. South African Medical Journal, 22, 551-553.

Wyndham, C. H., Strydom, N. B., Van Graan, C. H., Van Rensburg, A. J., Rogers, G. G., Greyson, J. S., & Van Der Walt, W. H. (1971, January) Walk or jog for health: The energy costs of walking or running at different speeds. South African Medical Journal, 16, 50-52.

Yanker, G. D. (1983). The complete book of exercisewalking. Chicago: Contemporary Books, Inc.

APPENDIX A

INFORMED CONSENT

Informed Consent Form

The Energy cost of Horizontal Speedwalking
in 18 to 40 Year Old Males

I, ______________________________, volunteer to participate in a study to determine the energy cost of horizontal speedwalking. I am willing to undergo the following: a combined, symptom-limited maximal graded exercise test with expired gas analysis prior to the training and testing sessions; a one-week, speedwalking training program; and two test sessions during which two submaximal speedwalking and running tests will be performed.

MAXIMAL OXYGEN CONSUMPTION

The evaluations will include a medical history, measurements of heart rate and blood pressure, expired respiratory gasses, and ECGs at rest and during exercise. Also, I will breathe room air through a mouthpiece and a nose clip will be attached such that my exhaled air can be collected. The exercise test which I will undergo will be performed on a treadmill with the amount of effort increasing gradually. This test requires a maximal effort, however, I understand I can stop the test at any time I desire. As with any exercise, there exists the possibility of adverse changes occurring during the test. For young subjects actively engaged in vigorous exercise as part of their daily lives, and who have no medical symptoms that contraindicate participation in exercise, this risk is no greater than that encountered in daily life. If any abnormal observations are noted at any time the test will be immediately terminated. During the performance of the test, trained personnel will keep under surveillance my pulse, blood pressure, and electrocardiogram.

There exists the possibility of certain changes occurring during the exercise test. They include abnormal blood pressure, pulse rate, and in very rare instances "heart attack". Every effort will be made to minimize the possibility of such undesirable changes by the observations during testing. Emergency equipment is available to deal with unusual situations which may arise. The purpose of this evaluation is twofold: 1) to identify any unknown problems related to the responses to exercise, and 2) to determine maximal oxygen uptake ($\dot{V}O_{2max}$).

I agree to participate in the one week, three-days-a-week training program and will give my best effort toward learning the speed walking technique. I understand that there is a chance that I may have some degree of muscle soreness or discomfort in the shin, thigh, groin, and shoulder areas. There is also a slight chance for a muscle pull. Each training session will last one hour and will be monitored to limit chances of injury or muscle soreness. All training will take place on the treadmills, in the Human performance Lab. At the end of the training program I will attend the pretest session to view an example test.

TEST SESSIONS

I agree to have my weight and height determined prior to each of the two test sessions. Also three electrodes will be applied to my chest for electrocardiographic monitoring and heart rate determination. In order to collect expired air during testing, I will be required to wear a nose clip and headset supporting a low resistance breathing valve and mouthpiece.

After a five minute rest period (sitting), I will begin walking at 2.0 and 2.5 miles per hour (mph) for the first minute and 3.0 for the next two minutes of the three minute warm up. At the end of the three minutes the speed will be increased for the required exercise. There are a total of four exercises which will include:

1) 4 mph, speedwalking
2) 5 mph, speedwalking
3) 4 mph, running
4) 5 mph, running

No more than two exercises will be performed per session and the sequence of exercises will be randomized.

The training sessions will give me time to experience and become familiar with the treadmill and exercises to be performed. Wearing the breathing apparatus may cause some discomfort, but should not produce any injuries. Heart rates and electrocardiograms will be monitored during the entire test session. If any abnormal physiological response is observed, the test will be stopped.

I consider myself to be in good health and to my knowledge I am not infected with a contagious disease or have any limiting physical condition or disability, especially with respect to my heart, that would preclude my participation in the tests as described. I have read the foregoing and I understand what is expected of me. Any questions that I had, were answered to my satisfaction. I, therefore, voluntarily consent to be a subject in this study although I may withdraw at any time.

____________________ (Subject) ____________ (Date)

____________________ (Witness) ____________ (Date)

APPENDIX B

SELF-ADMINISTERED PRE-EXERCISE MEDICAL HISTORY FORM

Self-Administered Pre-Exercise Medical History Form

Name ______________________ Date ____________

Date of Birth ____________

PAST HISTORY (Have you ever had?)	(Mark X if Yes)	Date
Rheumatic Fever	( )	______
Heart Murmur	( )	______
High Blood Pressure	( )	______
Any Heart Trouble	( )	______
Disease of Arteries	( )	______
Varicose Veins	( )	______
Lung Disease	( )	______
Operations	( )	______
Injuries to Back, Knees, Ankles, etc.	( )	______
Epilepsy	( )	______

Explain: ______________________

____

FAMILY HISTORY (Have any of your relatives had?)		Age	Relative
Heart Attacks	( )	___	______
High Blood Pressure	( )	___	______
High Cholesterol Levels	( )	___	______
Diabetes	( )	___	______
Congenital Heart Diseases	( )	___	______
Heart Operations	( )	___	______
Other	( )	___	______

Explain: ______________________________

____

PRESENT SYMPTOMS REVIEW (Have you recently had?)		Date
Chest Pain	( )	______
Shortness of Breath	( )	______
Heart Palpitations	( )	______
Cough on Exertion	( )	______
Cough up Blood	( )	______
Back Pain	( )	______
Swollen, Stiff or Painful Joints	( )	______
Do you awaken at night to urinate?	( )	______

Explain: ______________________________________

____

RISK FACTORS

1. Smoking — Yes / No

Do you Smoke? ( ) ( )

Cigarettes ( ) ( ) How many? ___ How many years? ____

Cigar ( ) ( ) How many? ___ How many years? ____

Pipe ( ) ( ) How many times a day? ___ Years? ____

How old were you when you started? ______________________

In case you have stopped, when did you? __________________

Why? ____

2. Diet

What is your weight now? ______ 1 year ago? _________

At age 21? ______ Are you dieting? _________

Why? ____

3. Exercise

Do you consider yourself healthy? _________

Do you run? _________

How many miles per week? _________

How many years have you been running? _________

Do you engage in other recreational activities? _______

What? ____

How often? ____

How long (minutes)? ______________________________________

How far (miles)? ____

How far do you think you walk each day? _______________

Is your occupation: Sedentary ( ) Active ( )

Inactive ( ) Heavy Work ( )

Do you have discomfort, shortness of breath, or pain with moderate exercise? __________

Were you a high school or college athlete? __________

Specify ____

APPENDIX C

INSTRUCTION SHEET

Instruction Sheet

The Energy Cost of Horizontal Speedwalking
in 18 to 40 Year Old Males

1) No strenuous exercise the day of the test.

2) DO NOT eat for three (3) hours before the test.

3) Bring a complete list of medications currently being taken.

4) Take your regular medicines (if any) before the scheduled test.

5) Get a good nights sleep before your test.

6) Bring a pair of shorts, shirt, and running shoes with you for your exercise test.

7) Plan to spend approximately one hour at the testing lab.

8) Locker and shower facilities are available for your convenience.

9) All tests will take place in the UW-La Crosse Human Performance Lab located on the second floor in the southeast end of Mitchell Hall (room 225).

10) If you do not feel well the day of the test or can not make it please tell me or call and leave a message at:

785-8685 --- Human Performance Lab
or
788-6723 --- Home phone

Thank you,

James G. Vils

APPENDIX D

SPEEDWALKING TRAINING PROGRAM HANDOUT

Speedwalking Training Program

I welcome you all to the one week training program you are about to undergo. The program will run for one hour every Monday, Wednesday, and Friday. Times will be 6:00 - 7:00 AM, 11:00 - 12:00, and 5:00 - 6:00 PM. If at any time you can not make it or are having difficulty please feel free to talk with me or call me at 788-6723 (late evenings after 9:00 or mornings before 8:00 are best). The training program is designed for you to work at your own speed and at no time should you attempt to exceed what you feel you are capable of. All training will take place in the Human Performance Lab. The training program has been designed as follows:

Day 1)
A. View video tape of speedwalking technique.
B. Practice as a group with the instructor.
   - heal toe strike.
   - thigh technique.
   - hip swivel.
   - head, neck, and torso position.
   - arm movements.
   - bent leg speedwalking.
C. Practice speedwalking on the treadmills.
D. Instructor will video tape subjects and make corrections or suggestions were needed.

Day 2)
A. Practice speedwalking on treadmills.
B. Instructor will video tape subjects and make corrections or suggestions were needed.
C. At the end of the period subjects will watch themselves on video.

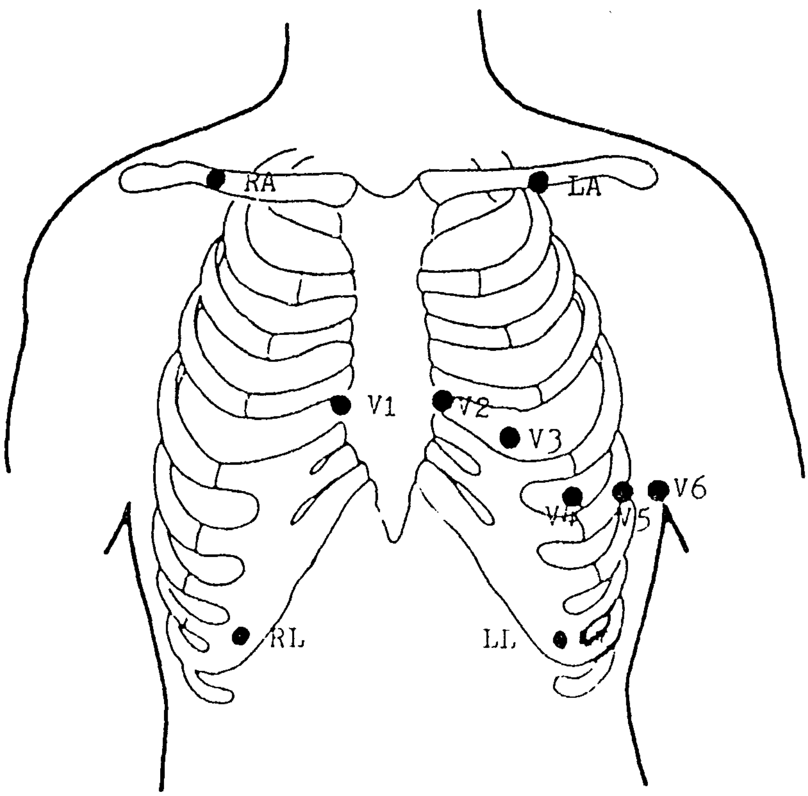
Day 3)
A. Practice speedwalking on treadmills.
B. Subjects will view an example submaximal test.
C. Subjects sign up for two dates which are convenient for them within the next two weeks.

APPENDIX E

TWELVE LEAD ECG ELECTRODE PLACEMENT

Twelve Lead ECG Electrode Placement

Ten Medi-Trace Offset disposable electrodes were used for the 12 lead ECG and placed on the subject as follows: Right and left arm electrodes placed at the midclavicular line, on the Clavicle. Right and left leg electrodes placed at the midclavicular line, about an inch above the bottom of the rib cage. The precordial electrodes V1 and V2 were positioned on either side of the sternum, at the fourth intercostal space. V4 was located at the midclavicular line, fifth intercostal space; V3 was set halfway between V4 and V2. V5 and V6 were placed on the same level with V4, in the anterior and midaxillary lines respectively. The diagram below illustrates the Twelve lead electrode placement described above.

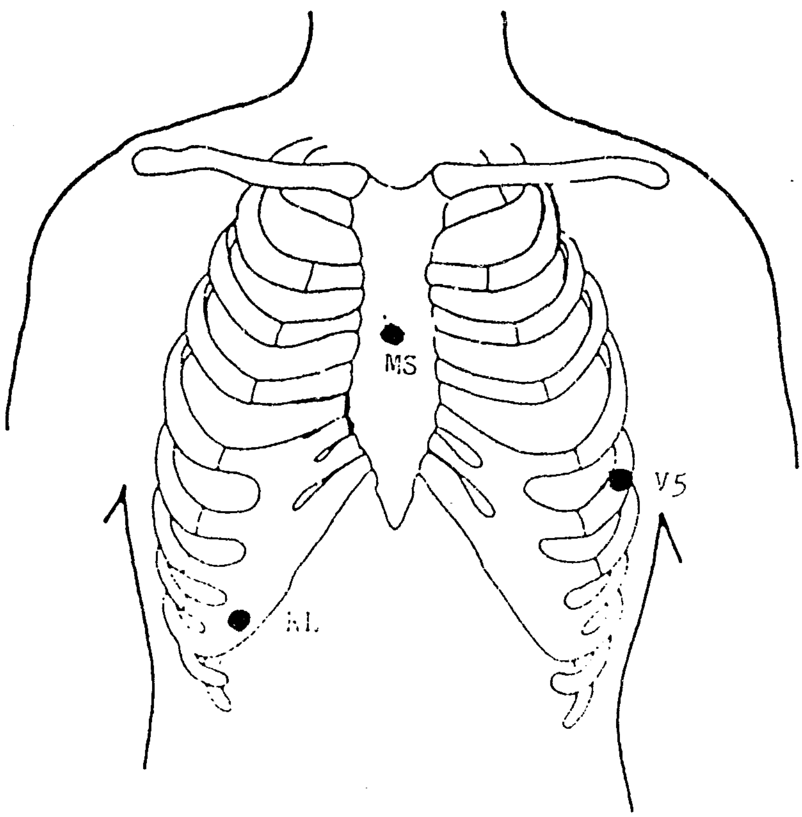


APPENDIX F

CM5 ELECTRODE PLACEMENT

CM5 Electrode Placement

Three Medi-Trace Offset disposable electrodes were used for the CM5 ECG and placed on the subject's chest as follows: Right leg electrode placed at the midclavicular line and inch above the bottom of the rib cage. MS electrode positioned on the midportion of the sternum and finally V5 located in the fifth intercostal space on the left chest wall anterior to the axilla. The diagram below illustrates the CM5 electrode placement described above.



APPENDIX G

PICTURE OF THE BECKMAN METABOLIC OXYGEN UPTAKE SET UP

APPENDIX H

TREADMILL CALIBRATION PROCEDURE

Treadmill Calibration

Before each test session, the Quinton pit treadmill was calibrated. the calibration procedure consisted of first measuring one revolution of the treadmill belt. The number of revolutions per minute at three, four, and five miles per hour with a belt length of 536 cm, was calculated to be 15 revolutions per minute for 3 mph, 20 revolutions per minute for 4 mph, and 25 revolutions per minute for 5 mph. The treadmill was then set at the required speed and checked for accuracy. The speed calibration was checked again with a subject actually walking on the treadmill.

APPENDIX I

SL-GXT RECORDING FORMS

BRUCE TREADMILL TEST

SUBJECT: ______________________ AGE: __________ RESTING B.P. _____/_____

DATE: ______________________ MAX. H.R. (predicted): __________ RESTING H.R. __________

PRE-EXERCISE MEASUREMENTS:

(1) SUPINE (EKG) H.R. = __________ B.P. = _____/_____

(2) STANDING (EKG) H.R. = __________ B.P. = _____/_____

(3) POST-HYPERVENTILATION (EKG) H.R. = __________ B.P. = _____/_____

STAGE	DURATION	SPEED MPH	ELEVATION (% GRADE)	METS	TIME MIN:SEC	H.R.	B.P.
**1	3 MIN.	1.7	10%	4.65	1:00 2:00 3:00		/ /
**2	3 MIN.	2.5	12%	7.05	4:00 5:00 6:00		/ /
**3	3 MIN.	3.4	14%	10.17	7:00 8:00 9:00		/ /
**4	3 MIN.	4.2	16%	13.49	10:00 11:00 12:00		/ /
**5	3 MIN.	5.0	18%	17.25	13:00 14:00 15:00		/ /
**6	3 MIN.	5.5	20%	24.60	16:00 17:00 18:00		 /
**7	3 MIN.	6.0	22%	28.40	19:00 20:00 21:00		/ /
**9	3 MIN.	6.5	24%		22:00 23:00 24:00		/ /
MAX. DATA:							/
IM POST EX.							/
1 MIN. RECOVERY		1.5	0%	2.15	1:00		/
2 MIN. RECOVERY		1.5	0%	2.15	2:00		/
4 MIN. RECOVERY		1.5	0%	2.15	4:00		/
6 MIN. RECOVERY		1.5	0%	2.15	6:00		/

If H.R. is less than 100, terminate test.
If H.R. is greater than 100, subject is to be seated after 6 minutes of recovery and H.R. and B.P. are to be monitored until H.R. is less than 100 or stabilizes.

** Stages 1-5 are calculated as walking speeds.
** Stages 6-7 are calculated as running speeds.

NAME: ____________ DATE: ________ TIME: ________ TEMP: ________ PBar: ________ AGE: ________

WEIGHT lbs ________ kg ________ HEIGHT in ________ cm ________ EXERCISE activity ________ hr/wk ________ miles ________

mph	% grade	$\dot{V}_E$	ml O_2	ml·kg	ml CO_2	RER	%CO_2	%O_2	H R	RPE	METs
1.7	10%										
1.7	10%										
1.7	10%										
2.5 -	12%										
2.5	12%										
2.5	12%										
3.4 -	14%										
3.4	14%										
3.4	14%										
4.2 -	16%										
4.2	16%										
4.2	16%										
5.0 -	18%										
5.0	18%										
5.0	18%										
5.5 -	20%										
5.5	20%										
5.5	20%										
6.0 -	22%										

	PRE	POST
O_2		
CO_2		

APPENDIX J

DESCRIPTION OF THE BORG RATINGS OF PERCEIVED EXERTION

Borg Scale of Perceived Exertion

At various times throughout your run I will hold up this scale and ask you to select the number that best represents how hard you feel the work is for you at that time. As you can see this scale ranges from a low of 6 to a high of 20. The higher the number the harder you feel the effort is for you. The highest number (20) should represent the maximum effort and fatigue level you have ever felt while exercising. There is no right or wrong answer. Just try to estimate your total feeling of exertion and effort as honestly and accurately as you possibly can.

6	
7	Very, very light
8	
9	Very light
10	
11	fairly light
12	
13	somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard

From: Butts, N.K. (1982). Physiological profiles of high school female cross country runners. Research Quarterly for exercise and Sport, 53, p. 9.

APPENDIX K

SUBMAXIMAL TEST RECORING FORM

NAME: ______ DATE: ______ TIME: ______ TEMP: ______ Pbar: ______ AGE: ______

WEIGHT lbs ______ kgs ______ HEIGHT in ______ cm ______ TEST# ______ TEST: 4.0 SW 5.0 SW 4.0 J 5.0 J

SPEED mph		min	$\dot{V}_E$	ml O_2	ml·kg	ml CO_2	RER	%CO_2	%O_2	H R	RPE	
REST		1.0										
		2.0										
		3.0										
		4.0										
		5.0										
2.0	5%	6.0										
2.0	5%	7.0										
3.0	10%	8.0										
3.0	0%	9.0										
		10.0										
		11.0										
		12.0										
		13.0										
		14.0										
		15.0										
		16.0										
		17.0										
		18.0										
		19.0										

APPENDIX L

FREQUENCY TABLE

ACCUMULATIVE PERCENTAGE OF SUBJECTS REACHING MAXIMUM HEART RATE

Frequency Table
Accumulative percentage of subjects reaching maximum heart rate

SW 4.0	F	Run 4.0	F	SW 5.0	F	Run 5.0	F	% of Subjects
72.73	1	85.79	1	93.57	1	88.83	1	0.0
71.88	1	80.44	1	92.19	1	86.46	1	2.7
71.78	1	77.60	1	91.75	1	86.08	1	5.4
70.90	1	77.54	1	91.49	1	82.89	1	8.1
70.10	1	73.68	1	90.71	1	82.51	1	10.8
68.85	1	73.51	1	89.16	1	82.18	1	13.5
67.49	1	72.77	1	88.61	1	81.77	1	16.2
66.49	1	70.44	1	87.43	1	79.53	1	*18.9
63.74	1	69.52	1	87.17	1	79.14	1	21.6
63.73	1	68.91	1	86.07	1	78.87	1	24.3
62.03	1	68.09	1	85.05	1	78.22	1	27.0
61.75	1	67.93	1	84.48	1	78.14	1	29.7
61.38	1	67.91	2	82.35	1	74.46	1	32.4
60.38	1			81.28	1	74.33	1	35.1
59.38	1	67.50	1	81.05	1	74.09	1	37.8
58.92	1	67.21	1	80.21	1	74.00	1	40.5
58.85	1	67.20	1	79.68	1	72.73	1	43.2
58.46	1	67.19	1	78.84	1	71.96	1	45.9
58.29	1	65.61	1	78.24	1	71.91	1	48.6
58.15	1	65.17	1	77.08	1	71.12	1	*51.4
57.71	1	64.65	1	76.77	1	70.81	1	54.1
57.50	1	64.00	1	76.72	1	70.39	1	56.8
57.37	1	63.79	1	76.70	1	70.15	1	59.5
57.07	1	63.68	1	76.50	1	69.84	1	62.2
56.18	1	63.64	1	75.54	1	69.79	1	64.9
55.15	2	63.04	1	72.63	1	69.71	1	67.6
		62.63	1	70.59	1	69.47	1	70.3
54.55	1	62.57	1	68.72	1	68.75	1	73.0
53.45	1	62.56	1	68.54	1	67.71	1	75.7
52.51	1	61.34	2	68.04	1	67.01	1	78.4
52.41	1			67.89	1	66.67	1	81.1
52.33	1	60.42	1	67.38	1	65.78	1	*83.8
51.34	1	59.89	1	65.80	1	64.25	1	*86.5
50.00	1	59.66	1	64.17	1	63.64	1	89.2
49.73	1	58.55	1	64.00	1	62.50	1	91.9
49.71	1	57.22	1	62.79	1	62.03	1	94.6
47.28	1	53.49	1	62.50	1	57.56	1	97.3

F = frequency
* = ACSM (1986) training heart rate level

APPENDIX M

FREQUENCY TABLE

ACCUMULATIVE PERCENTAGE OF SUBJECTS REACHING MAXIMUM MET VALUE

Frequency Table
Accumulative percentage of subjects reaching maximum MET value

SW 4.0	F	Run 4.0	F	SW 5.0	F	Run 5.0	F	% of Subjects
56.19	1	70.49	1	84.50	1	86.89	1	*0.0
49.61	1	68.99	1	80.95	1	81.97	1	2.7
49.18	1	66.94	1	80.33	1	77.14	1	5.4
48.00	1	65.57	1	79.51	1	77.12	1	8.1
46.72	1	62.77	1	77.97	1	74.97	1	10.8
45.90	1	62.71	1	76.00	1	73.55	1	13.5
45.76	1	61.90	1	73.72	1	72.09	1	16.2
45.45	1	60.47	1	72.73	1	70.80	1	18.9
45.22	1	57.60	1	72.09	1	69.60	1	21.6
43.41	1	55.86	1	71.90	1	64.00	1	24.3
43.37	1	53.33	1	68.28	1	63.04	1	27.0
41.67	1	50.98	1	67.47	1	62.76	1	29.7
40.69	1	50.00	2	66.87	1	60.24	1	32.4
39.86	1			66.67	1	58.82	1	*35.1
38.56	1	49.71	1	65.91	1	58.33	1	37.8
37.33	1	49.40	1	65.36	1	57.99	1	40.5
37.12	1	49.04	1	64.33	1	57.96	1	43.2
36.81	1	48.77	1	61.96	1	57.58	1	45.9
36.26	1	48.52	1	58.67	1	57.23	1	48.6
35.40	1	48.47	1	58.48	1	57.06	1	51.4
35.26	1	47.73	1	57.32	1	56.05	1	54.1
35.03	1	47.24	1	55.03	1	55.83	1	56.8
34.97	1	47.13	1	54.29	1	54.04	1	59.5
34.91	1	46.86	1	53.44	1	53.37	1	62.2
33.88	1	45.34	1	52.57	1	52.00	1	64.9
33.71	1	44.89	1	52.27	1	51.45	1	67.6
33.52	1	44.79	1	52.02	1	51.14	1	70.3
33.13	1	44.51	1	51.41	1	51.10	1	73.0
32.00	1	44.51	1	50.92	1	50.82	1	75.7
31.82	1	42.94	1	50.28	1	50.62	1	*78.4
31.64	1	42.37	1	49.73	1	50.59	1	81.1
31.49	1	40.74	1	48.82	1	50.29	1	*83.8
31.22	1	40.00	1	46.73	1	46.03	1	86.5
31.18	1	38.32	1	46.70	1	44.07	1	89.2
30.73	1	37.16	1	46.58	1	43.58	1	91.1
28.97	1	36.16	1	43.83	1	42.52	1	94.6
22.03	1	35.75	1	43.02	1	38.42	1	97.3

F = frequency
* = ACSM (1986) training MET level

APPENDIX N

SPEEDWALKING RECOMMENDATIONS AND INSTRUCTIONS

Speedwalking Recommendations and Instructions

Based on the results from this study certain recommendations can be made for those wishing to use speedwalking to increase their level of fitness or for those considering speedwalking as a prescribed exercise. In order to learn how to speedwalk it is advisable to begin by walking normally, slowly incorporating the exaggerated heel plant. At this point the foot should strike the ground in a flexed position at about a 45 to 90 degree angle to the shin. The knee should not be in a locked out position when heel contact is made, rather it should be slightly bent just as in normal walking. Once comfortable with the heel strike, arm motion should be incorporated. Arms should be carried in the sagittal plane with elbows held at a comfortable angle (e.g., at 45 to 90 degrees of flexion). Arm swing should be light at first and then more vigorous as exercise progresses. The individual ought to look straight ahead and stand erect as in normal walking.

Initial speedwalking sessions should be short and gradually increased in length. This will also enable the muscles, ligaments, and joints time to adjust to the new movement patterns. Overexertion may be avoided by monitoring heart rate and breathing. If prescribing speedwalking for an individual, it may be wise to actually test the person speedwalking on the treadmill. This would help to ensure that the individual is not over exerting himself/herself. One note to remember: speedwalking on level ground has somewhat a different feel than speedwalking on a treadmill. Therefore, speedwalking practice on the treadmill should precede testing.

Although speedwalking has been proven in this study to be a very viable exercise alternative with an ability to provide aerobic benefits, it is not without faults. Speedwalking, like any exercise, is not free from injury. It may not produce as many injuries as running for example but nonetheless potential for injury is there. Over use injuries may occur in the anterior portion of the tibia (shin splints), posterior portion of the knee, and in the groin, quadriceps, hamstring, and Gracilis muscles (muscle pulls) may appear. Some of the subjects in this study did complain of soreness in the above areas but none reported any injuries. If started slowly and in moderation, there is no reason why speedwalking should not become an integral part of one's exercise regime.