Physiological comparison of racewalking and brisk walking at three submaximal speeds in female recreational racewalkers

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A PHYSIOLOGICAL COMPARISON OF RACEWALKING AND
BRISK WALKING AT THREE SUBMAXIMAL SPEEDS
IN FEMALE RECREATIONAL RACEWALKERS

by
Craig A. Wagoner
B.A. California State University, Stanislaus, 1987

Presented in Partial Fulfillment
of the Requirements for the degree of
Master of Science

UNIVERSITY OF MONTANA
1989

Approved by
Chairman, Board of Examiners
Dean, Graduate School
Date
ABSTRACT

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A Physiological Comparison of Racewalking and brisk walking at three submaximal speeds in female recreational racewalkers (51 pp.)

Director: Arthur Miller

The purpose of this study was to determine if there was a significant difference ($p < .05$) in the energy expenditure between racewalking and brisk walking. Fifteen female recreational racewalkers volunteered for this study. Their mean ages were 35 years ± SD 7 years. Mean VO$_2$ max was 39.8 ml·kg$^{-1}$·min$^{-1}$ ± SD 5.44 ml·kg$^{-1}$·min. Each subject walked around an indoor oval track at 3, 4, and 5 miles·hour$^{-1}$ while brisk walking or racewalking. Expired gases were collected and analyzed for gas contents and volumes. There was no significant difference in energy expenditure between the two styles at any speed. A significant difference was found between the heart rates and VO$_2$ between the styles. The hypothesis was rejected.
Acknowledgements

Appreciation is duly warranted to those whom gave up their social and study lives in order that mine may continue. Special thanks goes to Dr. Mike Zupan for his unbounding knowledge and assistance in making this project a success, also, for challenging me in ways I never thought possible. Many thanks goes to Dr. Arthur "Tucker" Miller, for his insight into the research world and for the advise that brought me from start to finish. Thanks also goes out to Dr. Ken Dial for taking time out to participate on my committee. I also extend a great big THANKS to my fellow graduate students, Huw Griffiths, Zachary Mead and others, whom made it possible for me to continue when things were at their worst. I also like to say thanks to my father and mother who believed in me, encouraged me, and made many sacrifices for my family and myself to be here. Finally, and most importantly, I would like to extend my love to my wife Lori and my son Chad for being as patient as they were, and for making the sacrifices to be here.
DEDICATION

This thesis is dedicated to the memory of my sister,

Vikki Rae Wagoner
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CHAPTER I
Introduction

Almost all active individuals walk. For most, walking is the most common form of exercise. For some, walking represents the only physical activity outside sedentary living. Walking has derived from the basic transportation mode to what is now considered one of the better, and most convenient means of aerobic exercise and it is an effective way of improving cardiovascular fitness while reducing body fat (Frey, Doerr, Laubach, Mann & Glueck, 1982; Pollock, Cureton & Greninger, 1969). Walking has taken on several different names such as, mall walking, brisk walking, pace walking, and health walking (DeBenedette, 1988). This study will use the term brisk walking, as it most accurately describes the intended action of the study. Walking has also become a major form of sport competition in the United States and abroad. This competitive walking is duly named racewalking.

There have been numerous studies comparing walking with running (Epstein, Magazanik & Sohar, 1981; Francis & Hoobler, 1986; Hagberg & Coyle, 1984; Morgan & Martin, 1986; Santiago, Alexander, Stull, Serfass, Hayday, & Leon, 1987; Stamford, 1975). These studies have found that racewalking at speeds of 10 to 14 kilometers per hour (km·hr$^{-1}$) (6.2 to 8.7 miles per hour (miles·hr$^{-1}$)) elicits a higher volume of oxygen consumed (VO$_2$)
than running at the same speeds. Brooks and Fahey (1985) found that the oxygen consumption for racewalkers during treadmill walking at competition speeds was only slightly lower than the highest oxygen uptake during treadmill running. The economy of walking faster than 8 km·hr$^{-1}$ (4.97 miles·hr$^{-1}$) was one-half of that for running at similar speeds (Brooks & Fahey, 1985). The efficiency of the body during brisk walking may be as high as 30%, which is somewhat higher than running (Brooks & Fahey, 1985). The energy cost of brisk walking may vary within wide limits, not only among individuals but also with the same individual. Strand & Rodahl (1978) found this to be due to the influence of surface, total body weight, including clothes, varying speeds, and gradient. Another variable affecting walking economy is stride length. It has been found that freely-chosen stride length is more economical than stride lengths shorter or longer (Cavanagh & Williams, 1982; Morgan & Martin, 1986).

The purpose of this research project was to study the difference in energy expenditure between racewalking and brisk walking at different speeds in recreational racewalkers. Because of the increased popularity in racewalking, along with the lack of available information, a need exists for examining its energy costs.
The Purpose

The purpose of this study was to investigate the difference in energy expenditure between racewalking and brisk walking at 3 speeds in recreational walkers.

Delimitations

This study was delimited by the following:

1) 15 female, volunteer, racewalkers between the ages of 29 and 55 years.

2) The method of pacing the walkers (a bicycle with a computerized speedometer attached).

3) The method of gas collection to include:
   a) Douglas bags used for collecting and holding the expired gases.
   b) Tissot used to measure the volume of the expired gases.

Limitations

Because this study was conducted in the field it was limited to atmospheric and surface conditions of the indoor track, the temperature and the time of day these tests were conducted. It was also limited by the unregulated health habits of the subjects.
Assumptions

It was assumed that each subject followed the verbal directions concerning diet and activities prior to the testing trials. It was also be assumed that all subjects will perform to their greatest ability.

Hypothesis

The following hypothesis was investigated at an alpha level of p<.05.

Energy expenditure \((\text{VO}_2)\) while racewalking at 4.8, 6.4 and 8.05 km·hr\(^{-1}\) (3, 4 and 5 miles·hr\(^{-1}\)) will be greater than the energy expenditure while brisk walking at the same speeds on an indoor oval track in female recreational walkers.

Definitions

1. Steady State - The point in which energy demand is sufficiently met via metabolism.
2. Racewalking - Head and body lean slightly forward with arms bent at 90 degrees and locked. Arms are pumped tightly against the body for propulsion, no higher than the chest. The hips roll naturally in proportion to the stride while the knees bend as leg swing forward then straightens as it passes under the hip. The feet land heel to toe with one foot in contact with the ground at all times (Stone, 1988).
3. Brisk walking - This style is very similar to regular walking with the added feature of an exaggerated arm swing
and longer stride.

4. Recreational walkers - Those who do not compete in national walking events or do not compete at all. Those who walk for fitness 3 to 5 times per week.

5. Entrainment - Respiratory cycle synchronized with gait.
CHAPTER II
Review of the Literature

Introduction

Very few studies have been written comparing racewalking with brisk walking (Wyndham & Strydom, 1971). Present efforts in the field of walking have been concentrated on researching differences between walking and running (Cavagna & Kaneko, 1977; Cavanagh & Williams, 1982; Epstein, Magazanik & Sohar, 1981; Fellingham, Roundy, Fisher & Bryce, 1978; Hagberg & Coyle, 1984; Howley & Glover, 1974; Menier & Pugh, 1968; Santiago et al., 1987; Stamford, 1975; Van Der Walt & Wyndham, 1973), the effects of weighted and non-weighted walking has on metabolic factors (Blessey, Hislop, Waters & Antonelli, 1976; Booyens & Keatinge, 1957; Cavagna & Kaneko, 1977; Corcoran & Brengelmann, 1970; Cotes & Meade, 1960; Donovan & Brooks, 1977; Grimby & Sorderholm, 1962; Hagberg & Coyle, 1973), and numerous biomechanical factors have been considered (Murray, Guten, Mollinger & Gardner, 1983; Murray, Kory, Clarkson & Sepic, 1966; Sanzen, Forsberg & Westlin, 1986). Although these studies are important to the body of knowledge, they do not directly address the problem at hand. Individuals who choose walking as a mode of exercise, due to personal preference, illness, or injury, need to know which technique is best suited for their exercise goals. Such goals may include decreasing or maintaining a healthy level of body fat, increasing or maintaining cardiovascular endurance, or a
combination of both. This chapter contains a review of literature that is important so that one may understand where the trend in the walking field is concentrated. Also, this chapter will help to contribute a knowledge base so that one can understand the individualized factors that may influence any part of this recent study.

**Energy Cost of Walking**

The relationship between walking speed and oxygen consumption is approximately linear between the speeds of 3.0 and 5.0 km·hr$^{-1}$ (1.86 and 3.10 miles·hr$^{-1}$) (McArdle, Katch & Katch, 1985). At faster speeds, walking becomes less efficient and the relationship curves in an upward direction to indicate a greater caloric cost per unit of distance traveled (McArdle et al., 1985). Wyndham and Strydom (1971) concur that walking is more efficient at speeds under 8.1 km·hr$^{-1}$ (5.03 miles·hr$^{-1}$). These researchers further predicted that the oxygen consumption would be even greater at speeds higher than 11.3 km·hr$^{-1}$ (7.02 miles·hr$^{-1}$), providing that a person could walk at speeds this great. Many researchers agree that as walking speed increases energy expenditure increases, and economy decreases (strand & Rodahl, 1978; Brooks & Fahey, 1984; Cotes & Meade, 1960; Donovan & Brooks, 1977; McArdle, Glaser & Magel, 1971; McArdle et al., 1985; Pearce, et al., 1983; Zarrugh, Todd & Ralston, 1974). Donovan and Brooks (1977) support the above findings when they compared grade walking to horizontal walking during steady state...
exercise. The subjects walked at speeds of 3.0, 4.5 and 6.0 km·hr\(^{-1}\) (1.86, 2.79 and 3.73 miles·hr\(^{-1}\)). The researchers observed that muscular efficiency during walking is inversely related to speed and work rate. They also found that males between the ages of 21 and 30 achieved an efficiency level of 40.1\% while walking at 3 km·hr\(^{-1}\) (1.86 miles·hr\(^{-1}\)). A decreased efficiency level was observed at a higher treadmill walking speed of 6.0 km·hr\(^{-1}\) (3.73 miles·hr\(^{-1}\)). Collaborating work done by McArdle et al. (1985) reveals that the total caloric costs are greatest at the faster, less efficient, walking speeds. Figure 1 shows the energy expenditure of men who walked at speeds ranging from 1.0 km·hr\(^{-1}\) to 10 km·hr\(^{-1}\) (.62 to 6.21 miles·hr\(^{-1}\)) (McArdle et al., 1971). Menier and Pugh (1968) also support that walking is more efficient at speeds less than 8 km·hr\(^{-1}\) (4.97 miles·hr\(^{-1}\)). These researchers used four Olympic racewalkers to assess oxygen consumptions at various speeds. They report that the relationship between oxygen consumption and walking speeds up to 8 km·hr\(^{-1}\) (4.97 miles·hr\(^{-1}\)) followed an upward concave curve. This curve indicates that walking at speeds less than 8 km·hr\(^{-1}\) (4.97 miles·hr\(^{-1}\)) is more efficient than walking at speeds faster than 8 km·hr\(^{-1}\) (4.97 miles·hr\(^{-1}\)).
Figure 1. Energy expenditure while walking on level ground at different speeds.

Note. From Exercise Physiology (p. 149) by W. D. McArdle, F. I. Katch & V. L. Katch, 1985
These studies would indicate that energy expenditure is reliant on several different variables. Such variables include walking surface, grade, wind resistance, clothing, and speed of walking (strand & Rodahl, 1978; Pearce et al., 1983). strand & Rodahl (1978) finds that oxygen demand is greater when walking on level ground with a wind resistance of 18.5 meters per second, than when walking on asphalt with no wind and no grade.

**Walking vs. Running**

Many studies have been done comparing the energy expenditure between running and walking (Cavagna & Kaneko, 1977; Cavanagh & Williams, 1982; Epstein, Magazanik & Sohar, 1981; Fellingham, et al., 1978; Hagberg & Coyle, 1984; Howley & Glover, 1974; Menier & Pugh, 1968; Santiago et al., 1987; Stamford, 1975; Van Der Walt & Wyndham, 1973). Howley and Glover (1974) tested the caloric cost of walking and running one mile on a treadmill with 8 men and 8 women. Each subject walked at a speed of \(0.18 \text{ km/hr}^{-1}\) (\(0.11 \text{ miles/hr}^{-1}\)) and ran at a speed that was subjectively comfortable. The researchers reported that the gross caloric cost of walking was 1.08 kilocalorie·kilogram\(^{-1}\)·mile\(^{-1}\) (Kcal·kg\(^{-1}\)·mile\(^{-1}\)) for men and 1.15 kcal·kg\(^{-1}\)·mile\(^{-1}\) for women. The cost of running was 1.57 kcal·kg\(^{-1}\)·mile\(^{-1}\) for men and 1.73 kcal·kg\(^{-1}\)·mile\(^{-1}\) for women. The researchers ascertained that running a given distance required more calories than walking the same distance. And, women used significantly (\(p<0.001\)) more calories men. Thus, the researchers concluded that running a given distance required more
energy than walking the same distance (Howley & Glover, 1974). Hagberg & Coyle, (1984), Menier & Pugh, (1968), and Stamford, (1975) each found a crossover speed in which VO$_2$ achieve similar values while walking and running. This crossover speed is reported to be between 5.6 and 9 Km·hr$^{-1}$ (3.48 and 5.59 miles·hr$^{-1}$). Hagberg and Coyle (1984) sampled 8 competitive racewalkers to determine the speed where running and racewalking become equally efficient. They reported that running was more efficient at the faster speeds than racewalking. When running and racewalking were compared at similar oxygen consumptions, the other physiological parameters such as heart rate, ventilation, perceived exertion, and respiratory exchange ratio responses were identical. Racewalking and running also resulted in a similar maximal oxygen uptakes (VO$_2$ max). The results from these researchers (Hagberg & Coyle, 1984) indicate that the speeds (between 8 & 9 km·hr$^{-1}$) where racewalking and running become equally efficient are similar to the crossover speeds for conventional walking and running.

Stamford (1975) tested three groups of male subjects walking on a treadmill at 5.6 and 7.2 km·hr$^{-1}$ (3.5 and 4.5 miles·hr$^{-1}$) and running on a treadmill at 7.2, 8.8, 11.2 and 13.6 km·hr$^{-1}$ (4.5, 5.5, 7.0 and 8.5 miles·hr$^{-1}$). This researcher (Stamford, 1975) found that walking VO$_2$ max was significantly lower than running VO$_2$ max. Maximal oxygen uptake was similar over running speeds of 7.2 to 13.6 km·hr$^{-1}$ (4.5 to 8.5 miles·hr$^{-1}$). This researcher (Stamford, 1975) concurs with Hagberg and Coyle (1984)
that there was no discernable difference in heart rate, ventilation, and respiratory exchange ratio with reference to walking versus running.

Many researchers have found racewalking to be more efficient at the slower speeds, than running, and running to be more efficient at the higher speeds (Hagberg & Coyle, 1984; Stamford, 1975; Wyndham & Strydom, 1971; Cavanagh & Kaneko, 1977; Howley & Glover, 1974). These present studies indicate that running is more efficient at speeds higher than 8 km·hr⁻¹ (5 miles·hr⁻¹) than that of racewalking. They also demonstrate that racewalking is more efficient at the lower speeds.

Treadmill Testing vs. Field Study

It is important to determine if any differences in oxygen consumption exists due to techniques of data collection. In this present study a field study was used in which the subjects walked on an indoor, rubber track. This is in contrast to collecting data while the subjects walked on a treadmill in a laboratory. Much can be said for the convenience of the laboratory and the ease with which one can stand along side a subject to monitor data, trying to simulate, an other wise, believable circumstance. However, a significant difference was found between the energy cost of floor and treadmill walking (p<.05) (Pearce, Cunningham, Donner, Rechnitzer, Fullerton & Howard, 1983). For example at a speed of 4.78 km·hr⁻¹ (2.9 miles·hr⁻¹) the energy cost of treadmill walking was 10.58 ml·kg⁻¹·min⁻¹, and the energy cost of
floor walking was 11.04 ml·kg⁻¹·min⁻¹ (Pearce et al., 1983). Possible reasons for this difference may be due to proprioceptive and/or exteroceptive feedback. Air resistance and sensory feedback are important to balance which are different between the floor and the treadmill (Van Inguen Schenau, 1980). In addition Pearce et al. (1983) finds that energy expenditure at 5.6 km·hr⁻¹ (3.48 miles·hr⁻¹) was 10% lower on a treadmill than on asphalt or cinder. Ralston (1960) showed similar results when comparing walking on the treadmill to walking on linoleum. Using 4 male and 2 female adults, Ralston (1960) studied energy cost while walking at speeds of 2.93 and 5.86 km·hr⁻¹ (1.8 to 3.64 miles·hr⁻¹) on different surfaces. The subjects wore light, nonrestrictive clothing and rubber-soled shoes. Each subject walked for 10 minutes on the treadmill, then 10 minutes on the floor (the composition of the floor was no given). The researcher found that the energy expenditure while walking at 2.93 and 5.86 km·hr⁻¹ (1.8 and 3.64 miles·hr⁻¹) showed no significant difference among the means of floor walking versus treadmill walking. No studies were found comparing energy expenditure while on the treadmill to that while on a rubber floor.
Age and Gender Differences

The present study does not directly address age and gender differences, but it is important to explore this literature due to the age and gender (all females) used in the present study.

Many researchers have reported that the metabolic energy cost of walking is independent of sex and age (Strand, 1956; Blessey et al., 1976; Booyens & Keatinge, 1957; Corcoran & Brengelmann, 1970; Mahadeva, Passmore and Woolfe, 1953). Strand (1956) confirms that men and women have roughly the same mechanical efficiency during cycling and a step test. He also points out that metabolic rate (ml·kg$^{-1}$·min$^{-1}$) during walking is considered to be constant between age and gender. Blessey et al. (1976) studied 40 adults between the ages of 20 to 59 years. Five of each gender were in each of the following age groups: 10 to 29, 30 to 39, 40 to 49, and 50 to 59 years. Each subject walked around an oval track at approximately 60 and 120 steps per minute. The researchers concludes that there was no significant differences related to sex or age. They also point out that in subjects between the ages of 20 and 59 the metabolic cost of walking was not a consideration. The major factor determining the energy cost was the speed.

However, some researchers have found that age does influence the energy cost of walking and further reported that walking efficiency decreases with age (Durin & Mikulicic, 1956; Grimby & Soderholm, 1962; Pearce et al., 1983). Pearce et al. (1983) sampled 42 males between the ages of 19 and 66 years (19-29 years
Each subject was subjected to a maximal oxygen consumption test on a treadmill. The researchers found a significant interaction of age with both floor and treadmill. Due to the lack of agreement on this subject one cannot generalize energy expenditure to age or gender.

**Mechanics of Walking Styles**

It is important to distinguish the difference between the mechanics of racewalking and brisk walking. Racewalking is commonly referred to as the "ostrich" gait. The heel of the front foot must touch the ground before the toe of the back foot pushes off. The leading leg must be straight at the knees as the body passes over it. The arm (90 degrees at the elbow) moves as a sprinter's, pumping diagonally across to the bodies center line. These motions produce a rolling action of the hips (Brand 1987). Murray et al. (1983) studied 2 world class racewalkers. The purpose of their study was to identify the changes in movement patterns and muscle activity in racewalkers. They found a sagittal rotation of the ankle, knee, and hip in each athlete during initial floor contact of the same foot. When compared to normal walking, the ankle of the racewalker was in less dorsiflexion during the stance phase and more dorsiflexion at heel strike and during swing phase. In addition, during midstance the racewalkers hyperextended the knee an average 9°, while the normal walkers averaged 1° (Murray et al., 1983). These researchers (Murray et al., 1983) also found that the
during normal fast walking, the shoulder moved through an average range from $31^\circ$ of hyperextension to $8^\circ$ of flexion. However, during racewalking peak shoulder hyperextension averaged $85^\circ$ and peak flexion averaged $34^\circ$.

Racewalking is a very mechanically complicated mode of exercise (Lennart, Forsberg & Westlin, 1986; Van Inguen Schenau, 1980). The above paragraphs only introduces one to this mode.

Normal walking, or brisk walking, is accomplished at the higher speeds using a longer stride. The elbows should remain at 180 degrees. Arm swing is proportional to leg swing.
CHAPTER III
Methodology

Subjects

The subjects were 15 female recreational racewalkers from Missoula who volunteered to participate in this study. Their ages ranged from 29 to 55 years. Each subject met American College of Sports Medicine (ACSM) guidelines for submaximal exercise testing (ACSM, 1986).

Preliminary Procedures

Approval from the University of Montana Institutional Review Board was secured prior to commencement of this project. In addition, each subject was informed of the purpose of the study and was given an explanation of the investigation. Every subject was informed of the benefits to be expected, and the right to terminate any test at any time. All individuals signed an informed consent statement (Appendix A) acknowledging an understanding of the above explanations. Also, each subject completed a medical history form (Appendix B).

Research Methods

Each subject that met the guidelines for a graded exercise test established by the American College of Sports Medicine (1986) performed a maximal oxygen consumption (VO₂ max) test while racewalking or running on a motor driven treadmill. Six (6) subjects declined to participate or did not meet the ACSM
guidelines (1986) age criteria for a maximal test. All subjects performed 6 independent sub-maximal walking tests. These tests consisted of 3 independent sub-maximal oxygen consumption tests while either racewalking or brisk walking on an indoor oval track. Descriptive data was collected including height, weight, and age. Residual volumes were calculated (Pollock, Wilmore & Fox, 1984) and percent body fat was estimated by the hydrostatic weighing method.

Maximal Treadmill Test

Nine subjects performed a maximal oxygen consumption test on a Quinton Motor Driven Treadmill Model 643. A modified Balke protocol was used for the maximal tests. Prior to exercise, seated resting metabolic data was gathered for a period of 3 minutes. A 1 minute transition period was instituted to allow for speed and grade adjustment and subject orientation of the treadmill. A 3 minute warm-up period consisting of 1.34 km·hr\(^{-1}\) (3 miles·hr\(^{-1}\)) at 0 percent grade will was performed prior to each maximal test. All subjects were verbally encouraged to perform to maximal limit. The tests were discontinued when maximal level was reached or at the request of the subject. Following maximal exercise, subjects initiated an active recovery while speed and grade were reduced to 1.34 km·hr\(^{-1}\) (3 miles·hr\(^{-1}\)) and 0 percent grade, respectively. The treadmill was stopped after a 3 to 5 minute active recovery. Heart rate was continuously monitored until it dropped below 100 beats per minute (bpm) or fell within 20 beats of the resting heart rate.
Modified Balke Protocol

Following the 3 minutes of warm-up at 3 miles·hr⁻¹, the speed was increased to 4.5 miles·hr⁻¹ (2 km·hr⁻¹) and a grade of 0 percent. The grade was then increased at a rate of 2 percent each minute until the end of the test. The treadmill speed remained constant for the entire test.

Oxygen Consumption

Oxygen consumption was measured with a Beckman Metabolic Measurement Cart. Each subject breathed through a Hans-Rudolph respirator mask. With the exhalation port of the mask being connected to a mixing chamber. Expired air was pumped from the mixing chamber (500 mL·min⁻¹) through a drierite cylinder to various transducers and sensors into a Beckman OM-11 Oxygen Analyzer and a Beckman LB-2 Medical Gas Analyzer. Both analyzers were calibrated before each test using a known concentration of mixed gases (O₂ = 16.19%, CO₂ = 3.92%). Temperature compensated barometric pressure and signal conditioning are packaged into an integrated chip. Temperature was monitored with a monolithic chip transducer. The data from the various transducers and sensors were converted from analog to digital data, which was then transferred to a programmable calculator in the control panel. The data were then calculated and displayed minute by minute as VO₂ (mL·min⁻¹ and mL·kg⁻¹·min⁻¹), VE (L·min⁻¹), fractional concentration of oxygen and carbon dioxide in expired air (FECO₂ and FE0₂), and respiratory exchange ratio (RER).
Sub-maximal Test

Each subject performed 6 sub-maximal tests while racewalking or brisk walking on an indoor track. Each trial consisted of 4.8, 6.76, or 8.05 km·hr⁻¹ (3, 4, or 5 miles·hr⁻¹) using either walking technique. The speed was paced using a standard touring bicycle equipped with an Avocet Bicycle Computer that was calibrated on a Quinton Motorized Treadmill up to 6 miles·hr⁻¹. Each subject began the sub-maximal test with a 2 minute warmup while walking at 4.8 km·hr⁻¹ (3 miles·hr⁻¹). The last 30 seconds of the warmup served as a transition period to allow for the correct speed to be reached. Following the warm-up period, the subject walked around the outside lane of an indoor track (.14 Km per lap), for 4 minutes. At the beginning of the fourth minute the gas collection began by turning the triple J valve from ambient air to the Douglas Bag. At the end of the fourth minute the gas collection stopped by turning the triple J valve from the Douglas Bag to the ambient air. A 2 minute active recovery followed each walking bout. A 10 minute rest period was initiated between speeds to allow the subjects to recover. The order of speed and technique were randomized using a random numbers table which was computer generated by a statistical software program.
Sub-Maximal Gas Collection

Each subject wore a Hans-Rudolf Respirator mask. The exhalation port was connected to a 7 m (length), 38 mm diameter flexible hose connected to a Triple J 3-way valve which was connected to a 150 L Douglas Bag. The valve and the Douglas Bag were temporarily mounted to a battery powered Golf cart. The golf cart was driven around the track along side of the subject during each trial. Gas collection began at the fourth minute of exercise, and lasted for 1 minute. The third to fourth minute of exercise is the point in which heart rate stabilizes, or steady state is achieved (Fox, Bowers, & Foss, 1988; Golding, Myers, & Sinning, 1982).

Sub-Maximal Gas Analysis

Collected exhaled gas concentrations were analyzed with a Beckman Metabolic Measurement Cart in the Human Performance Laboratory at the University of Montana. The Douglas Bag, filled with exhaled gas, was connected to the Beckman via a 3 mm plastic tube and a 3-way Cock Valve at the drierite cylinder. The Beckman drew exhaled gas at a rate of 500 mL·min\(^{-1}\) through the drierite cylinder to various transducers and sensors into a Beckman OM-11 Oxygen analyzer and a Beckman LB-2 Medical Gas Analyzer. Both analyzers were calibrated using a known concentration of mixed gases. The data collected from the Beckman were percentage concentrations of oxygen (O\(_2\)) and carbon dioxide (CO\(_2\)).
The volume and temperature of each Douglas bag was measured using a Warren E. Collins 600 Liter Gasometer. The gases were drawn from the Douglas bag by the gasometer via a 7 m (length), 38 mm flexible hose and a Triple J 3-way valve. This volume, along with expired gas concentrations and barometric pressure, were used for computations of \( V_O_2 \) (L min\(^{-1}\) and mL kg\(^{-1}\) min\(^{-1}\)), \( V_CO_2 \) (L min\(^{-1}\)), \( V_E \) (L min\(^{-1}\)) and respiratory exchange ratio (RER) (Appendix E).

Heart Rate

A Burdick single channel electrocardiogram was used to monitor heart rates on all subjects that completed the maximal treadmill test. A (CMS) three lead configuration was used. All heart rate data were recorded during the final 6 seconds of each minute.

A Computer Instruments Corporation (CIC) Model 8799 heart rate monitor was used during the sub-maximal field tests. A transmitter was placed on the middle of the chest, across the sternum, in the fifth intercostal space using two disposable electrodes, or the CIC provided strap. The transmitter sends an output signal to a receiver located inside a wristwatch. The watch was worn by the subjects during each trial. The signal received from the transmitter is digitalized into a small microcomputer inside the watch which stored the average heart rate every minute. The stored heart rates were recalled and recorded at the Human Performance Laboratory.
Data Analysis

Statistical data analysis was computed using SPSS-x statistical program integrated with a VAX computer. A multivariate analysis of variance (MANOVA) was used to test the difference among the means of walking styles, the speeds, and the styles by speeds. The alpha level was set at the p<.05 level to determine statistical significance. All data are expressed as mean ± SD.
Chapter IV
Results and Discussion

Results

The subjects were 15 female recreational racewalkers. Their descriptive data is presented in table 1. Tables 2, 3, and 4 demonstrate the results of a multivariate analysis of variance (MANOVA) showing no significance ($p < .05$) between racewalking and brisk walking for $V_{O_2}$, $V_{E}$, and RER. There was an expected significant difference among all physiological parameters within the speeds. Table 5 shows that a significant difference was achieved between racewalking and brisk walking with $V_{CO_2} \ F(1, 14) = 5.22, p > .038$. Table 6 shows a significant difference between the heart rates of the two styles during all three heart rate sampling minutes, 3 minutes $F(1, 14) = 10.29, p > .006$, 4 minutes $F(1, 14) = 19.93, p > .001$, 5 minutes $F(1, 14) = 22.42, p > .000$. There were no significant differences found within the interaction of speed by style for $V_{O_2}$, $V_{E}$, RER, and $V_{CO_2}$. However, Table 6 demonstrates the interaction of speed by style for each heart rate was significant at each minute sampled, 3 minutes $F(2, 28) = 3.42, p > .047$, 4 minutes $F(2, 24) = 3.36, p > .049$, 5 minutes $F(2, 24) = 3.42, p > .047$. Although not significant, there was a consistent relationship between $V_{O_2}$ while looking at the interaction of speed by style (see Figure 2). This figure shows that racewalking at all three speeds yielded a higher $V_{O_2}$ than did brisk walking at the same speeds.
Table 1

**Subject Descriptive Data**

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<th></th>
<th>Age</th>
<th>Wt kg</th>
<th>Ht cm</th>
<th>VO2 max</th>
<th>%fat</th>
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<tr>
<td>SD</td>
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**Note.**

a N=15
b N=8
c N=10

Table 2

**MANOVA Data for VO2**

<table>
<thead>
<tr>
<th>VO2 (ml/kg/min)</th>
<th>DF</th>
<th>E Score</th>
<th>P Probability</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.99</td>
<td>.337</td>
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<tr>
<td>Within Speed</td>
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<td>104.76</td>
<td>a</td>
</tr>
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<td>Speed x Style</td>
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**Note.** p < .05

a Significance
Table 3

**MANOVA Data for VE**

<table>
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<th>VE (L/min)</th>
<th>DF</th>
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<th>P Probability</th>
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<tr>
<td>Within Speed</td>
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*Note.* *q < .05*

*a* Significance

---

Table 4

**MANOVA Data for RER**

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<tr>
<td>Speed x Style</td>
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</table>

*Note.* *q < .05*

*a* Significance
### Table 6
**MANOVA Data for VCO2**

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<th>VCO2 (L/min)</th>
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<th>P Probability</th>
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<td>(a) .000</td>
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<td>.691</td>
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**Note.** \(q < .05\)

\(a\) Significance

### Table 6
**MANOVA Data for Heart Rates**

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<th>E Score</th>
<th>P Probability</th>
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<td>4 Speed x Style</td>
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<td>5 Speed Style</td>
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**Note.** \(q < .05\)

\(a\) Significance
Figure 2. The energy expenditure between the two styles (VO2, the amount of oxygen consumed by the body in 1 minute).
Discussion

Racewalking vs. Brisk Walking.

This present study demonstrates (table 2) that there is no significant difference in energy expenditure between racewalking and brisk walking at the three speeds tested (4.8, 6.4 and 8.04 km·hr⁻¹; 3, 4, and 5 miles·hr⁻¹), for female walkers between the ages of 29 to 55. Stamford (1975) concurs that changes in walking speed and variations in walking styles have little or no effect on VO₂. This may be due to several factors. The low speeds in this study reflects the findings of Cavagna and Franzetti (1981). Cavagna and Franzetti (1981) determined that racewalking shows a greater efficiency at speeds greater than 8 km·hr⁻¹ (5 miles·hr⁻¹) than regular or brisk walking. However, they do point out that a maximum efficiency is to be expected at intermediate speeds of approximately 5 km·hr⁻¹ (3.1 miles·hr⁻¹). Racewalking efficiency increases with higher speeds mainly because the increase of efficiency with speed is associated with the mechanics of locomotion, which allows a maximum storage of mechanical energy in the muscles (Cavagna & Franzetti, 1981).

Another explanation for a greater efficiency with increasing speed is that of Cavagna and Kaneco (1977). They point out that increasing efficiency with increasing speed is to be expected when positive work is mainly due to the recoil of previously stretched muscles. Figure 2 shows the non-significant relationship between racewalking and brisk walking at the three
speeds for VO\(_2\). The present study expected to find a significant difference in energy expenditure between racewalking and brisk walking. The postulations expected racewalking to achieve a greater VO\(_2\) than brisk walking. Although the findings were not significantly different it is noted that racewalking consumed more energy than brisk walking at all three speeds (see Figure 2). If a brisk walker could reach greater speeds one might find a crossover speed between racewalking and brisk walking. That crossover speed may fall between 8 and 8.8 km·hr\(^{-1}\) (5 and 5.5 miles·hr\(^{-1}\)). This would make racewalking more efficient at the faster speeds.

The volume of carbon dioxide expired (VCO\(_2\)) was significantly different between the two walking styles (see Table 5), \(F(1, 14) = 5.22, p > .038\). This difference may be due to the biomechanical nature of racewalking. The expired carbon dioxide may have increased because of the gait of racewalking causing an increased step frequency. This increased step frequency may have increased respiration due to an entrainment affect, causing a hyperventilatory response. Bramble and Carrier (1983) found that there was evidence that breathing was entrained to gait. They conclude that breathing and gait were tightly coupled. Figure 3 shows the relationship between the two styles for VCO\(_2\). Stride length is exaggerated during regular or brisk walking at the slow and fast speeds. This would infer that the muscles are working harder during racewalking, increasing the production of CO\(_2\).
Figure 3. The relationship between the styles for the volume of carbon dioxide expired in 1 minute (VCO2).
Heart rate showed significant differences between styles also, (see Table 6) at all three minutes sampled. In all cases racewalking obtained the higher heart rates. This may be due to the arm movement and position during racewalking. This may also be due to the increase in step frequency while racewalking. Also, Workman and Armstrong (1986) point out that keeping ones balance while racewalking is a major consideration, which may cause certain muscles to work harder to keep this balance consequently raising the heart rate. McArdle et al. (1985) suggest that other factors may influence an increase in heart rate. Such influences may be emotions, food intake, and temperature all of which could not be controlled in this present study.

There were no significant differences in VO$_2$, VE or RER (tables 2, 3 & 4), between the two styles. Wyndham and Strydom (1971) finds similar results when these researchers compared 25 ordinary walkers to 1 racewalker. They found no difference in the oxygen consumption between the group and the racewalker. Hagberg and Coyle (1984) concur that racewalking and ordinary walking showed no difference at speeds less than 8 km·hr$^{-1}$ (5 miles·hr$^{-1}$). All the researchers further predicted that a crossover speed would be attainable at higher speeds greater than 8 km·hr$^{-1}$ (5 miles·hr$^{-1}$) (Hagberg & Coyle, 1984; Wyndham et al., 1971).
**Speeds**

There was an expected significant difference in scores between the speeds (see Tables 2, 3, 4, & 5). This is due to increased work output. As energy needs increase (increased speed), energy output increases (increased associated physiological parameters) (Brooks & Fahey, 1984; McArdle, Katch & Katch, 1985; Shaver, 1981)

**Speed by Style.**

There were significant differences in heart rates between speed and within the interactions of speed and style (see Table 6). This may be due to the increased step frequency encountered during racewalking and the exaggerated stride during brisk walking. As demonstrated in Figures 4, 5, and 6, the heart rates for both walking styles show a parallel relationship at the slower speeds. This would indicate that at the slower speeds racewalking is less efficient than brisk walking. McArdle et al. (1985) suggest that a less efficient type of exercise will cause a higher heart rate than a more efficient exercise at the same work load. It is not until 8 km·hr$^{-1}$ (5 miles·hr$^{-1}$) that the heart rates for both styles begin to come together suggesting that an interaction could take place at a faster speed greater than 8 km·hr$^{-1}$ (5 miles·hr$^{-1}$). This interaction may have occurred due to the inefficiency of brisk walking and the efficiency of racewalking at the higher speed of 8 km·hr$^{-1}$ (5 miles·hr$^{-1}$). This interaction may also suggest that a crossover
speed may exist between racewalking and brisk walking at speeds greater than 8 km·hr\(^{-1}\) (5 miles·hr\(^{-1}\)).

Minute ventilation (VE), although not statistically different, achieved similar values for racewalking and brisk walking at 8 km·hr\(^{-1}\) (5 miles·hr\(^{-1}\)). This may have been due to the increase in CO\(_2\) causing ventilation to increase (McArdle et al., 1985).
Figure 4. Mean heart rates at 3 minutes of steady state exercise.
Figure 5. Mean heart rates at 4 minutes of steady state exercise.
Figure 6: Mean heart rates at 5 minutes of steady state exercise.
CHAPTER V
Summary, Conclusion, and Recommendations

Summary

The primary purpose of this study was to determine which style of walking required more energy at three different speeds (4.8, 6.4 and 8 km/hr), racewalking or brisk walking. The subjects were 15 female recreational racewalkers from Missoula, Montana. All subjects walked at three different speeds while racewalking or brisk walking during which time expired gases were collected. The literature focused primarily on 4 different aspects, walking versus running, age and gender differences, energy cost of normal walking, and treadmill versus floor walking.

Each subject walked on an indoor track while their expired gases were sampled during brisk walking or a racewalking. The subjects walked at 4.8, 6.4 and 8 km·hr⁻¹ (3, 4 and 5 miles·hr⁻¹). The gas sampling period lasted for 1 minute, during which heart rates were also recorded.

A MANOVA was performed on the data along with descriptive analysis of height, weight, age, and percent fat. The MANOVA design is illustrated in tables 2, 3, 4, and 5.

The findings revealed that neither style was significantly different (p<.05) in energy expenditure at any of the three speeds. Racewalking yielded higher VO₂’s, although not significantly different, when compared to brisk walking at the three sub-maximal speeds (see Figure 2). Heart rates and VCO₂ were significantly different during racewalking at all speeds. These may have resulted due to an increased step frequency associated with racewalking.
Conclusions

Based on the analysis of data at $p < .05$ the research hypothesis can be rejected. Energy expenditure while racewalking was not found to be significantly greater than brisk walking in 15 female recreational walkers between the ages of 29 and 55 years. However, figure 2 reveals that energy expenditure is consistently greater while racewalking than while brisk walking at the same speeds. The heart rates and $\text{VCO}_2$ were significantly different, which may be due to the increased step frequency during racewalking causing a respiratory entrainment.

Recommendations

The following are recommendations offered by this researcher:

1) A study designed to investigate energy expenditure between racewalking and brisk walking in elite racewalkers at speeds greater than 8 km/hr (5 miles·hr$^{-1}$).

2) Conduct a study to determine a prediction equation for energy expenditure while racewalking.

3) Use the information in this study to establish training or fitness goals for individuals who choose walking as a mode of exercise.

4) A study designed to incorporate physiological aspects as well as biomechanical aspects needs to be investigated. To further explain this notion of entrainment.
Appendix A
Informed Consent

Explanation of the Graded Exercise Test
You will perform a maximal graded exercise test on a motor driven treadmill. The exercise intensity will begin at a level you can easily accomplish and will be advanced in stages depending on your fitness level. You may stop the test at any time because of personal feelings of fatigue or discomfort. We will stop the test at any time because of signs of cardiovascular fatigue.

Explanation of sub-maximal Exercise Test
You will also perform 6 sub-maximal walking tests on an indoor track. The exercise intensity will remain constant throughout each trial. However, the intensity may increase or decrease by speed for each trial. You may stop the test at any time for any reason but are encouraged to finish. We will stop the test at any time because of signs of fatigue.

Risks and Discomforts
There exists the possibility of certain risks during the test. They include abnormal blood pressure, fainting, irregular heart beat, and in rare cases heart attack and death. Every effort will be made to minimize these risks through the preliminary examination and by observations during the test. Emergency equipment is available if the need arises.

Benefits to be Expected
The information obtained from the maximal and sub-maximal tests provides a quantitative analysis of an individual’s capacity for aerobic energy transfer. This information may also aid in developing an exercise prescription for recreational racewalkers, a training program for racewalker racers, and a greater awareness of energy expenditure while walking at either technique.

Inquiries
Any questions about the above procedures are encouraged. If you have any doubts or anxieties, please ask us for further explanations. The numbers where you can reach us are, 243-5528 or 243-5257.

Freedom of Consent
Your permission to perform these tests is voluntary and you are free to deny consent if that is your desire.

Consent
I have read this form and I understand the tests and procedures that I will undertake. I consent to participate in this study.
Appendix B
Medical History Questionnaire

Name:_________________________ Date:__________

I.D.#_________________________ Phone#__________

Address:______________________ City:____________

Date of Birth:__________________ Age:____________

Sex:_______ Height:_______ Weight:_______

Person to contact in an emergency:_________________

Personal Physician:_________________

1. Have you ever been told by a physician that you have or have had any of the following (please check the appropriate response):

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<th>No</th>
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</table>

2. Please list any drugs, medications, or dietary supplements prescribed by a physician, or over the counter, that you are currently taking:

________________________________________________________________________

________________________________________________________________________

3. Is there a history of heart disease, heart attack, elevated cholesterol levels, high blood pressure or stroke in your immediate family (grandparents, parents, brothers and sisters) before the age of 60? Yes () No ()

4. Do you smoke now? Yes () No ()
   a. If yes, how many cigarettes do you smoke per day? _______
   b. If no, have you ever smoked? Yes () No ()
      1b. How long ago did you quit? _______
Appendix B (cont)

5. Are you currently under a great deal of stress either at work, school, or personally? Yes () No ()

6. Do you actively relieve stress through exercise, meditation or other methods? Yes () No ()

7. Are you currently on an exercise program? Yes () No ()
   If yes check the following:

   Type of exercise: () walking () bicycling () tennis
   () aerobics () swimming () racquetball
   () other ___________________________

   Frequency per week: () 1-2 times/week () 3-4 times/week
   () 5 or more times/week

   Duration (each day): () < 15 minutes () 15-30 minutes
   () 30-45 minutes () > 45 minutes

8. While exercising do you ever feel limited by (if yes, state type of activity you are performing when this arises):

   a. Breathing Yes No
   b. Chest, arm or neck pain () () Activity:________________________
   c. Low back pain () () Activity:________________________
   d. Pain in leg, relieved by rest () () Activity:________________________
   e. Side aches () () Activity:________________________
   f. Lower leg pain () () Activity:________________________
   g. Extreme long lasting fatigue () () Activity:________________________

The answers to this questionnaire are true and complete and to the best of my knowledge I am in good health.

Signed:_____________________________ Date:____________________
### Appendix C

**MAXIMUM OXYGEN CONSUMPTION DATA SHEET**

**NAME** ____________________________  **WEIGHT (kg) ____ (lb)____

**WATER TEMP. _______**  **TARE WHT _______**  **H2O WHT _______**

**HEIGHT (inches) _______**  **AGE ______ yrs _______ months**

**BP ____________________________**

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<th>STAGE</th>
<th>MINUTE</th>
<th>MPH</th>
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### Appendix D

**SUBMAXIMAL OXYGEN CONSUMPTION**

#### DATA SHEET

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**Barometric pressure:**

**Weight:**

**Ambient Temp:**

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*Note: The table is left blank for data entry.*
Appendix E

Computations

\[ V_E \; (L\cdot min^{-1} \text{ ATPS}) = (\text{rate}) \; (\text{volume}) \]

\[ V_E \; (L\cdot min^{-1} \text{ BTPS}) = V_E \; (L\cdot min^{-1} \text{ ATPS}) \times \left( \frac{310}{(273 + T)} \right) \times \left[ \frac{\left( P_B - P_{H2O \; \text{at} \; T} \right)}{(P_B - 47)} \right] \]

\[ V_{O2} \; (L\cdot min^{-1}, \text{STPD}) = V_E \; (L\cdot min^{-1}, \text{STPD}) \times \left( \text{true O}_2 \; \text{difference, dry} \right) \]

True O\(_2\) difference, dry = 0.265 - (1.265 \times F_{EO2}) - (0.265 \times F_{ECO2})

\[ V_{CO2} \; (L\cdot min^{-1}, \text{STPD}) = V_E \; (L\cdot min^{-1}, \text{BTPS}) \times 0.826 \times F_{ECO2} \]

RER = \[ V_{CO2} \; (L\cdot min^{-1}, \text{STPD}) / V_{O2} \; (L\cdot min^{-1}, \text{STPD}) \]
References


