A Comparative Study of the Oxygen Uptake Between Nonmotorized and Motorized Treadmills

Michael S. Wood
Utah State University

A COMPARATIVE STUDY OF THE OXYGEN UPTAKE BETWEEN NONMOTORIZED AND MOTORIZED TREADMILLS

by

Michael S. Wood

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ABSTRACT

A Comparative Study of the Oxygen Uptake Between

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Michael S. Wood, Master of Science

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Major Professor: Dr. Lanny J. Nalder
Department: Health, Physical Education and Recreation

The purpose of this study was to determine the effects of nonmotorized treadmill walking and motorized treadmill walking on VO_2 results, measured in $ml \cdot kg^{-1} \cdot min^{-1}$, of males and females, ages 20-30 at Utah State University, Logan, Utah, USA. The participants were required to walk at a pace of 3 miles per hour and 13% grade for a total exercise time of 9 minutes. The exercise time was broken up with 3-minute recovery periods. Oxygen uptake was measured continuously using a metabolic measurement cart. The data obtained from the metabolic cart were correlated for each treadmill to determine the degree of relationship.

A t test for correlated means was used to determine if there was a significant difference, alpha < 0.05, when measuring VO_2 and metabolic (MET) results. A significantly low correlational coefficient was found when the Proform Dual Motion Crosswalk Cross Trainer motorized treadmill (CW TM) VO_2 and MET results were compared with the Jane Fonda nonmotorized treadmill (Jane TM) and Voit 502 MD nonmotorized treadmill (Voit TM) VO_2 and MET results ($r = 0.3$, $p < 0.0001$). These results enabled the researchers to reject the null hypotheses, which stated there would be no significant difference and a high positive correlation between nonmotorized and motorized treadmill VO_2 and MET results. Standard mean difference effect sizes were calculated for the non-motorized treadmills versus the motorized treadmill. An effect size of 1.62 was found when both nonmotorized treadmills were compared with the motorized treadmill. This, combined with the significant difference, $p < 0.0001$, provided confidence that a Type I error was avoided. Therefore, the results of this research study show a significant difference in VO_2 and METs measured on a nonmotorized treadmill when compared with a motorized treadmill.

(59 pages)

DEDICATION

I would like to dedicate this thesis to Janet and Owen, my mother and father, without whom this would have not been desired or possible. I would also like to include Melissa, Joshua, and Carley, my wife, son, and daughter, without whom this would be meaningless. You have all encouraged and supported me in my educational goals. Thank you for your love, patience, and collective shoulders to lean on. I love you.

Michael Wood

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Michael Wood

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CHAPTER I

INTRODUCTION

Maximal aerobic capacity (VO_2 max) has gained acceptance as being the most accurate and important determinant in measuring aerobic fitness (Ong, 1993; McArdle, Katch, & Katch, 1991). VO_2 results make up the foundation of many research studies, and these results help determine many physiological factors. For example, Ong (1993) and Hammond and Froelicher (1984) used VO_2 when studying cardiac and pulmonary fitness. Inbar et al. (1994) used VO_2 measurements to determine if there was a decline in aerobic power with age. Their research found that aerobic power (VO_2 max) declined at an average yearly rate of 0.33 ml $0_2 \cdot kg^{-1} \cdot min^{-1}$. VO_2 is also used to determine the efficiency of other physiological parameters such as heart rate, respiratory exchange ratio, rate of respiration, and plasma lactate concentrations in relation to peak exercise (Kyle, Smoak, Douglass, & Deuster, 1989). With the increasing interest in exercise and exercise equipment, it is important that proven physiological measurements such as VO_2 be used to determine the validity of the exercise mode and the equipment used.

This increased interest in exercise has brought about many innovative exercise modalities and enhancements. For example, there have been studies comparing the effects of phosphate loading (to enhance exercise efficiency) and maximal oxygen uptake (Cade et al., 1984). Researchers have also looked at how horizontal walking compares to graded walking on a treadmill, how track walking can be used to estimate VO_2 max, and the difference in VO_2 when measured on a Stairmaster and a motorized treadmill (Kline et al., 1987; Luketic, Hunter, & Feinstein, 1993; Montoye, Ayen, Nagle, & Howley, 1985, respectively). Other researchers (Londeree, Thomas, Ziogas, Smith, & Zhang, 1995) have studied comparisons between percent $VO_{2\,max}$ and percent Heart Rate (max) for six exercise modes: motorized treadmill, cycle, skier, shuffler skier, stepper, and rower. All of these different exercise modes studied by these different researchers were found to produce different VO_2 results.

One common variable found in current studies researching exercise modes or equipment is the measurement of $VO_{2\,max}$. For decades, researchers have been developing nomograms and equations to predict $VO_{2\,max}$. Astrand and Ryhming (1954) were two of the first researchers to develop a nomogram to predict $VO_{2\,max}$. Their reasons for developing a nomogram to predict $VO_{2\,max}$ have remained consistent throughout the years. They stated that the direct measurement of maximal oxygen intake is a very intricate, potentially dangerous method and can only be performed in a well equipped laboratory. Many researchers have agreed with these limitations to direct $VO_{2\ max}$ measurement and have developed submaximal and field tests to predict $VO_{2\ max}$ (Cooper, 1968; Ebbeling, Ward, Puleo, Widrick, & Rippe, 1991; Hermiston & Faulkner, 1971; Kline et al., 1987; Laukkanen, Pekka, Pasanen, & Vurori, 1992; Latin & Elias, 1993; Margaria, Aghemo, & Rovelli, 1965; Metz & Alexander, 1971; Montoye et al., 1985; Siconolfi, Cullinane, Carleton, & Thompson, 1982; Widrick, Ward, Ebbeling, Clemente, & Rippe, 1992; Zwiren, Freedson, Ward, Wilke, & Rippe, 1991). Each of the prediction equations uses various correction constants that have been developed using regression analyses. These constants are used to correct for interindividual differences. For example, Cooper's (1968) 12-minute field test to predict $VO_{2\ max}$ in $ml \cdot kg^{-1} \cdot min^{-1}$ is expressed, $VO_{2\ max}$ = 3.126 x (meters covered in 12 minutes) - 11.3. Kline et al. (1987) has expressed his one-mile walk prediction equation as $VO_{2\ max}$ (in $ml \cdot kg^{-1} \cdot min^{-1}$) = 132.853 - (0.0769 x body weight) - (0.3877 x age) + (6.315 x gender) - 3.2649 x time) - (0.1565 x HR). These are only two examples of the many equations in use today. The American College of Sports Medicine (ACSM, 1995) has published an exercise guidelines text containing many $VO_{2\ max}$ prediction equations for many different exercise modes. These exercise modes include graded treadmill walking and running, leg ergometry, arm ergometry, and stepping. The $VO_{2\ max}$ prediction equation for walking on a motorized treadmill is divided into three sections, a resting component, a horizontal component, and a vertical component. The vertical component is needed when there is a grade involved. When this is the case, a corrections factor of 0.5 is multiplied into the vertical component. The ACSM (1995) guidelines state that even with the 0.5 constant, this prediction equation does not apply to graded, over-ground walking. This introduces the issue that graded, over-ground walking and graded, motorized treadmill walking may produce different $VO_{2\,max}$ results. Reasons for this difference are vague and unproven. Gamble, Bartlett, and Jakeman (1988) suggested a possible reason is the difference in the horizontal forces generated between over-ground and motorized treadmill conditions. They also point out that there are kinematic differences between over-ground and motorized treadmill walking.

One exercise mode that may produce similar kinematic forces as over ground conditions is walking on a nonmotorized treadmill. If graded, motorized treadmill walking produces different VO_2 results than graded, over-ground walking, it is therefore possible that graded, motorized treadmill walking will produce different VO_2 results than graded, nonmotorized treadmill walking. Despite the importance of VO_2 in measuring fitness, no research has examined the possible differences in VO_2 results between motorized and nonmotorized treadmills. Gamble et al. (1988) are the only group of researchers to discuss a potential reason for an increased VO_2 results when stride has been controlled while walking on a nonmotorized treadmill as opposed to walking on a motorized treadmill based upon observations made during their study. They stated that the runner on the nonmotorized treadmill has to generate and then maintain belt speed. The frictional characteristics of the belt system decelerate the belt whenever the runner is airborne. Therefore, there is an increased requirement for horizontal force application to be made by the runner during the contact phase. The runner has to generate a greater force at foot take-off, thereby increasing the belt speed greater than the average speed to allow for belt deceleration. This increased force may cause the VO_2 increase when using a nonmotorized treadmill.

This study determined if there is a significant difference in VO_2 results, measured in $ml \cdot kg^{-1} \cdot min^{-1}$, between motorized and nonmotorized treadmill walking. There are many research questions that could be discussed but the following questions guided this study.

Research Questions

1. Will VO_2 results obtained from non-motorized treadmills significantly differ from the VO_2 results obtained from a motorized treadmill?

2. Will a high positive correlation be found between the VO_2 results

obtained from nonmotorized treadmills and motorized treadmills?

Problem Statement

The purpose of this study was to determine the effects of nonmotorized treadmill walking and motorized treadmill walking on VO_2 results, measured in $ml \cdot kg^{-1} \cdot min^{-1}$, of males and females, ages 20-30 at Utah State University, Logan, Utah, USA.

Null Hypotheses

1. There will be no significant difference in VO_2 results between nonmotorized and motorized treadmills.

2. There will be no significant difference in metabolic equivalents (METs) between nonmotorized and motorized treadmills.

3. There will be a high positive correlation between nonmotorized and motorized treadmill VO_2 results.

4. There will be a high positive correlation between nonmotorized and motorized treadmill MET results.

CHAPTER II

REVIEW OF LITERATURE

The increased public interest in exercise and exercise equipment has brought an increased interest to the scientific community. Researchers are looking in all directions to study and validate claims made by the rising public interest. The research studies used in this review of literature were located using various reference tools, such as CD-ROM searches of Medline, Sport Discus, Mayo Foundation Research Library, and Dissertation Abstracts. Three specific subareas were searched for this study. The first of these is the importance of $VO_{2\ max}$ and VO_2 when researching fitness. Next is the different VO_2 results obtained from different exercises modalities and, finally, how VO_2 is affected by differences in walking patterns.

VO_2 and Fitness

The measurement of a person's maximal oxygen consumption ($VO_{2\ max}$) or, simply, his/her oxygen consumption (VO_2) is and has been used in research in a variety of ways. Astrand and Ryhming's (1954) nomogram to predict $VO_{2\ max}$ using achieved heart rate from a step test, a treadmill test, and a cycle test was the beginning of quantifiable fitness evaluation. Today many researchers have published equations to predict $VO_{2\ max}$. All of these researchers and their equations have one common denominator--knowing an individual's maximal capacity for oxygen consumption can uncover potential work capacity, disease incipience and progression, and athletic ability, and the list continues into many areas. Aitken and Thompson (1988) looked to see if oxygen uptake and the respiratory VCO_2/VO_2 exchange ratio (R) could be used to predict $VO_{2\ max}$. They discovered the R response to maximum incremental exercise may be influenced by different modes of physical training. VO_2 analysis is used as the gold standard to verify different exercise protocols and prediction equations. As stated in the previous chapter, the ACSM has published many equations to predict $VO_{2\ max}$ from different exercise modes. Many researchers have tested these equations using direct VO_2 measurement in a laboratory. Montoye et al. (1985) tested the ACSM's prediction equations for graded, motorized treadmill walking. They found that the ACSM's formulas for predicting VO_2 are accurate for estimating the mean oxygen requirement in grade walking from 6% to 18% in adult males. In horizontal walking and running at a 3% grade, the formulas underestimate VO_2 in all age groups of males. In boys under age 18, they underestimate the energy requirement for walking at all grade levels. Latin and Elias (1993) also looked at the ACSM's prediction equations for walking and running. They performed three different motorized treadmill tests to determine $VO_{2\ max}$, maximum heart rate, and oxygen costs for submaximal walking and running. They used both male and female subjects, N = 53 (males = 28, females = 25). They found that when the ACSM's estimates of oxygen cost of walking and running were used with the Astrand-Ryhming method, reasonably accurate predictions of $VO_{2\ max}$ were obtained for their group of subjects. They reported correlation coefficients of $r = 0.82$ and $r = 0.86$ for walking and running, respectively. Parker, Hurley, Hanlon, and Vaccaro (1989) used VO_2 as a guideline for measuring exercise intensity. They found that aerobic dance elicits a lower relative exercise intensity than that of running. From these examples it is clear that the measurement of VO_2 is a major factor in research, but, is $VO_{2\ max}$ the only variable researchers can look at when studying fitness levels? Martin, Heise, and Morgan (1993) looked at not only aerobic demand, but also kinematic and kinetic-based estimates of mechanical power output and energy transfer along with total body angular impulse to explain interindividual differences in walking and running economy. They found that mechanical power, energy transfer, and angular impulse expressions frequently used in the analysis of gait explain only a small proportion of normal interindividual variability in the aerobic demand at a given speed of walking or running. Brandon and Boileau (1992) also looked at different variables in their study of middle-distance runners. They reported that $VO_{2\,max}$ was the most important limitation for middle-distance runners followed by stride length, aerobic capacity, and power. Chronotropic incompetence is another variable often coupled with VO_2 in research. Chronotropic incompetence was first coined by Myrvin Ellestad in his research of heart rate response and ischemic heart disease. This phenomenon occurs when a person's functional capacity, as measured using heart rate, does not correspond with his/her age. Chronotropic incompetence is used to explain a person's decreased cardiac function, pulmonary function, or aerobic power (VO_2). Steinhaus, Dustman, Ruhling, and Emmerson (1988) and Inbar et al. (1994) found that the physiological profiles of older active men very closely resembled profiles of active men who were 30 years younger than those of older sedentary men. This shows the importance of maintaining a high aerobic fitness level throughout life. Lehmann, Berg, Kapp, Wessinghage, and Keul (1983) are another group of researchers who studied more than VO_2. They looked at correlations between running time, lactate threshold, VO_2 max, and catecholamine responses. Their correlations were found to be less significant than relations between oxygen intake, $VO_{2\,max}$, or the submaximal catecholamine-lactate product and field results. They concluded that the submaximal catecholamine-lactate product is a better performance index of field results than lactate or catecholamine levels alone. VO_2

is also used in studies of specific populations. Rowland and Green (1988) studied possible physiological differences between adults and children. They looked for adult-child differences in females and found that the physiological responses to exercise were similar to previous research studies between adult and child male subjects. Elite athletes such as marathon runners and professional football players have been studied using VO_2 measurements. Maron and Horvath (1988) looked at how aerobic power was affected after a competitive marathon. They found no decrease in the runners' VO_2. Hoette, Clark, and Wolff (1986) used VO_2 to look at the cardiac function of 146 professional football players and found the results were higher than predicted values. Laukkanen et al. (1992) studied the validity of a 2-kilometer walk test used to estimate $VO_{2\ max}$ for overweight adults. They stated that most prediction equations are not valid for an overweight or obese population. They reported correlation coefficients between measured and predicted $VO_{2\ max}$ of $r = 0.77$ for women and 0.75 for men. They suggested that the 2-kilometer walk test is reasonably valid when predicting $VO_{2\ max}$ for overweight men and women. Donnelly et al. (1992) studied 95 obese (BMI $\geq$ 28 kg/m^2) females to develop a $VO_{2\ max}$ prediction equation for submaximal exercise. They chose to use an over-ground 0.5-mile walk test to insure completion of the test by the subjects. They measured heart rate, rates of perceived exertion, and time. They used these results and a treadmill-measured $VO_{2\ max}$ to generate an equation to reliably predict $VO_{2\ max}$ for this obese population.

Hence, it has been shown that VO_2 is used for a variety of reasons, from the generation of prediction equations to the study of fitness levels of special populations. The measurement of a person's maximal oxygen consumption or, simply, a person's oxygen consumption is as important in today's research as it was for the research of Astrand and Ryhming back in 1954.

VO_2 and Exercise Modes

In an ideal world, all exercise equipment and modalities would elicit an increase in either a person's endurance or strength. Unfortunately, this is not an ideal world and there are many exercise gimmicks claiming to increase a person's functional exercise capability. Fortunately, the measurement of $VO_{2\ max}$ can be used to validate the effectiveness of the many different types of exercise equipment and modalities. The number of exercise accouterments on the market today is too great to cover in this section. Therefore, this section will cover only a small variety of the exercise modes available and discuss their validity.

One of the most common forms of exercise is walking. Researchers have studied walking in many different forms, ranging from horizontal walking, uphill walking, and downhill walking, to walking in deep water and walking backwards in order to measure the effects of fitness. Wanta, Nagle, and Webb (1993) used VO_2 to measure at what negative percentage grade produced significant changes in VO_2. They found that changes occurred over a wide negative grade range between -6% to -15%. They stated the possible reasons for this were different individual walking characteristics and walking speed. Green, Cable, and Elms (1990) studied the effects of walking on land compared to walking in deep water on heart rate and oxygen consumption. They reported significant differences in VO_2 measurement when measured on a treadmill as compared with deep water walking. Flynn, Connery, Smutok, Zeballos, and Weisman (1994) compared cardiopulmonary and lactate responses to forward and backward walking and running. They reported that backward walking and running produce significantly ($p < 0.001$) higher VO_2, heart rate, and blood lactate levels than forward walking and running.

Walking and running have also been studied in combination with other factors. Cooke, McDonagh, Nevill, and Davies (1991) studied the effects of different weight loads on oxygen intake in trained boys and men during treadmill running. They found that vertical loading of 5% to 10% of body mass did not produce a significant increase in the VO_2 response of either the boys or the adults. In contrast, they reported that horizontal loading produced significant ($p < 0.001$)

VO_2 increases in both groups. Martin (1985) also studied the physiological effects of loading the lower extremities during running. Martin studied five different load conditions in which he added weights to either the thigh or feet of 15 healthy males. He then had the subjects run on a motorized treadmill while their VO_2 and heart rates were measured. The results indicated the VO_2 and heart rate increased as load increased on both the thighs and feet. Martin concluded that the increase in VO_2 was a result of the increased load on the lower extremities and not because of the kinematic changes resulting from the increased loads placed on the lower extremities. Loading the lower extremities is not the only option people have if they want to walk or run with weights. Hand weights are a popular piece of equipment that has been studied. Owens, Al-Ahmed, and Moffatt (1989) and Bond, Tearney, Balkissoon, and Banks (1987) looked at the effectiveness of hand-held weights and found that there is no increase in oxygen consumption during exercise when they are used. Bryant, Goss, Robertson, Metz, and Feingold (1993) also studied the effects of hand-weighted exercise. Their dependent variables included more than simply $VO_{2\,max}$; they included peak heart rate, peak ventilation, and peak respiratory exchange ratio. They found that when uphill treadmill running was compared with uphill treadmill walking while pumping hand weights, there were no significant differences with respect to any of the dependent variables.

Fortunately, we have many other exercise options to choose from to help us gain a greater fitness level. For example, Hoffman et al. (1994) studied the physiological differences of uphill roller skiing using either a diagonal stride technique or a double pole technique. The authors concluded that (a) the economy of the double pole versus the diagonal stride technique of going uphill is dependent upon the incline, and (b) the VO_2 results were similar for both the double pole and the diagonal stride technique. Luketic et al. (1993) and Howley, Colacino, and Swensen (1992) studied the oxygen uptake of the Stairmaster stepping machine and found that the computer programs in the Stairmaster overestimate peak VO_2. They also found that true MET values (metabolic equivalents) were about 20% lower than those specified by the Stairmaster computer settings. VO_2 is used to determine the safety of exercise equipment as well as effectiveness. Sparrow, Parameshwar, and Poole-Wilson (1994) found that a 9-minute walking test on a nonmotorized treadmill is a safe method of assessing functional capacity in patients with all grades of heart failure. A final study of Londeree et al. (1995) reviewed six modes of exercise to measure their effects on maximum heart rate and $VO_{2\,max}$. The six modes of exercise included a motorized treadmill, cycle ergometer, skier machine, shuffle skier, stepper, and rower. The results suggested that weight bearing exercise modes have similar % $VO_{2\,max}$ and % heart rate maximum regressions. However, weight-supported and arm exercise modes appear to have different regressions, suggesting that these modes of exercise do not increase VO_2 as easy as weight-bearing exercise. Thus, it can be seen that the measurement of VO_2 can play an important role in verifying the claims made by proponents of certain exercise modes because, after all, this is not an ideal world.

VO_2 and Walking Pattern

As researchers have studied the human gait pattern, many factors have been shown to be of importance. These factors include stride length, stride time, stride frequency, horizontal and vertical ground forces, practice, and individual versus controlled pace selection. Each of these factors has been investigated to see how or if they affect $VO_{2\,max}$.

Many studies have consistently demonstrated that the aerobic demand of walking or running at controlled speeds curvilinearly increases as stride length is either lengthened or shortened, and thus stride rate is either increased or decreased from the preferred condition of the individual (Cavanagh & Williams, 1982; Cotes & Meade, 1960; Heinert, Serfass, & Stull, 1988; Knuttgen, 1961; Martin & Morgan, 1992; Morgan & Martin, 1986). These studies demonstrate the importance of controlling stride length and rate when VO_2 is used as the dependent variable. Other researchers have studied stride rate or cadence while looking at the energy cost of running. Brisswalter and Legros (1994) found that stride rate (cadence) is a very stable measure when measuring the energy cost of running. When compared with measures of ventilation, respiratory frequency, heart rate, and lactate concentration, stride rate was the most stable measure for assessing the efficacy of procedures aimed at improving the energy cost of running. Everyone has his/her own unique stride length. Bailey and Messier (1991) wanted to see if individual variations in stride length had any effect on running economy. These researchers used college-age male novice runners as their subjects. They used two groups and trained each group for 7 weeks. One group was able to use their own stride length and the other had their stride length controlled. The authors determined that at submaximal exercise there is no significant difference in VO_2 between the two groups. The fact that these researchers found stride length to be insignificant in the measurement of submaximal VO_2 has not inhibited other researchers to control stride length for various reasons. For example, Hreljac and Martin (1993) wanted to study the relationship between smoothness of stride and the economy of walking. Therefore, the researchers used a metronome to control the subjects' stride length while they held the treadmill speed constant. The metronome enabled the researcher to control cadence for a specific speed. They tested five different stride lengths and found a weak but statistically significant negative correlation between VO_2 and jerk cost. This finding suggests that smoothness and economy are not complementary performance criteria during walking.

Another group of researchers studied stride gait and VO_2 in heart failure patients. Davies, Greig, Jordan, Griene, and Lipkin (1992) found that in heart failure patients, there is a 15% increase in oxygen consumption as a result of their shortened stride gait. They concluded that a short-stepping gait may contribute to the limitation of exercise capacity in heart failure patients. Not all researchers have found the evaluation of stride to be an important determinant when looking at VO_2. Berry, Bacharach, and Moritani (1985) looked at stride frequency and ventilation. They found that, although stride frequency is important, the measurement of ventilation is more closely aligned to the metabolic state rather than stride frequency. Craib et al. (1994) studied the daily variation of stride length in trained male runners and concluded that stride length is of small concern when other testing conditions are controlled. When studying the human gait pattern and VO_2, it is easy to see that there are many possible angles one can take. A final study by Gamble et al. (1988) compared the running pattern between non-motorized treadmills, motorized treadmills, and over-ground walking conditions.

The researchers used a metronome to control for stride speed. They found a marked change in the running pattern on the nonmotorized treadmill when compared with the motorized treadmill and over-ground conditions. It should be noted that the nonmotorized treadmill used in this study required the use of a harness. This harness was attached to the subject during the test. The authors noted that early observations suggest that there was an increase in energy cost of running on the nonmotorized treadmill as compared to the motorized treadmill compared to the motorized treadmill and over-ground conditions. This was not quantified with data. The authors also reported, through kinematic analysis, that the running patterns differ on the nonmotorized treadmill when compared to relatively similar motorized treadmill and over-ground conditions. The non-motorized treadmill required modification of the temporal and kinematic components of running patterns. One research question that arises from this study stems from the researchers' suggestion that a nonmotorized treadmill causes an increase in energy cost when compared with a motorized treadmill. As yet there is no research that quantifies their suggestion that a nonmotorized treadmill elicits a greater energy cost than does a motorized treadmill.

Thus, we can see that the human gait pattern and its many dimensions play a role in the measurement of human performance. Therefore, when researching oxygen consumption, human gait characteristics need to be taken into consideration.

CHAPTER III

METHODOLOGY

The purpose of this study was to determine the effects of nonmotorized treadmill walking and motorized treadmill walking on VO_2 results of males and females, ages 20-30 at Utah State University.

Subjects

Participants for this study were recruited from the department of Health, Physical Education and Recreation at Utah State University. All subjects were enrolled in an exercise physiology class during Winter Quarter 1995. Fifteen males and 15 females were used in this study. Statistical power for detecting a moderate difference defined in this study as 0.75-1.00 standard deviations with a sample size of 30 and a Type I error rate of 0.05 will be 0.83-0.97, respectively. The subjects were asked to sign an informed consent form (appendix A) and meet the following criteria (appendix B):

1. Be between 20 and 30 years of age.

2. Have not smoked in the past 6 months.

3. Have no current cardiac or pulmonary problems that may be affected by exercise.

4. Have no orthopedic problems that may be aggravated by walking on a treadmill.

The subject selection criteria used in this investigation were based on convenience for the population available, possible metabolic measurement problems due to smoking, and the desire to insure a safe testing procedure for each subject. Subjects who met the above criteria were scheduled for the study.

Instrumentation

Anthropometric measurements (appendix B) were taken by the researcher for each subject in the study. These measurements were taken at the Utah State University Human Performance Lab. Metabolic measurements were obtained using a Sensormedics 2900 Metabolic Measurement Cart (MET Cart) during the exercise protocol. The study incorporated the MET Cart's breath mixing chamber, automatic maximum oxygen uptake ($VO_{2\,max}$), spirometry, and automated interpretation of test data. The MET Cart was internally and externally calibrated for flow of O_2 and CO_2 concentration prior to each testing session according to the specifications of the manufacturer (Sensormedics Corp., Yorba Linda, California, USA). The calibration reports are shown in appendix C. The treadmills used in the study included the Proform Dual Motion Crosswalk Cross Trainer motorized treadmill (CW TM), the Voit 502 MD nonmotorized treadmill (Voit TM), and the

Jane Fonda nonmotorized treadmill (Jane TM). The arm-action component of the Proform motorized treadmill was not used during the testing procedure. Each treadmill was calibrated to a 13% grade elevation, which remained constant throughout the study. A metronome was used to measure and control subjects' cadence during the exercise procedure as outlined by previous researchers (Bailey & Messier, 1991; Gamble et al., 1988; Hreljac & Martin, 1993). Subjects wore exercise attire for the exercise portion and each subject wore the same pair of shoes while walking on each treadmill.

Methods of Procedure

The following procedures were based upon a pilot study performed by the same researcher using the same instrumentation during the summer of 1995. The selection of the treadmills was based on consumer popularity. The percent grade elevation, treadmill speed, and treadmill walking stage time used in the study were based on pilot-study data. In combination, a 13% grade elevation, 3-mph speed, and 3-minute treadmill walking stages increased subjects' heart rates and VO_2 measurements to a steady-state within each exercise stage. This leveling off of VO_2 and heart rate or steady state phase was observed for each treadmill. The findings of the pilot study were used in the justification of the exercise protocol used in this investigation.

Subjects who qualified for the study were assigned a research identification number. The testing procedure, in its entirety, was explained in detail and any questions were answered. The subjects were then asked to sign the informed consent form (appendix B). Anthropometric measurements were taken and study criteria questions were answered for each subject. The anthropometric information was then entered into the MET Cart. Subjects were given time to find their own stride cadence on a motorized treadmill set at 3 mph as outlined by previous researchers (Bailey & Messier, 1991; Holt, Hamill, & Andres, 1991). Cadence (revolutions/minute) for each subject was measured using a metronome. Subjects were given a sterile mouthpiece and had the physical logistics of the test explained to them. These included moving from one treadmill to another and how to breathe correctly into the mouthpiece. An electronic metronome was used throughout the test to insure each subject maintained the 3-mph pace on the non-motorized treadmills. During the test, a test monitor was present to adjust a subject's stride cadence in case it slowed or sped up and to stabilize the subject while moving from one treadmill to another. At the end of the test, VO_2 results were retrieved from the MET Cart database and made ready for statistical analysis. To alleviate possible block effects due to treadmill order in the exercise protocol, a randomized block design of time and treatment order was used. The following study exercise protocol was used (Table 1).

Table 1

Exercise Protocol

Phase	Stage Time	Cumulative Time
1. Baseline data	3 minutes	3 minutes
2. Exercise period	3 minutes	6 minutes
3. Recovery period	3 minutes	9 minutes
4. Exercise period	3 minutes	12 minutes
5. Recovery period	3 minutes	15 minutes
6. Exercise period	3 minutes	18 minutes
7. Recovery period	3 minutes	21 minutes

Research Design

The design chosen for this study was a correlational study. This design tested the study's null hypotheses regarding possible differences in VO_2 results, measured in ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, and MET results between nonmotorized and motorized treadmills.

Statistical Design

Descriptive statistics were used to show the physical characteristics of the subjects. These physical characteristics included age (yr), weight (kg), height (cm), and stride cadence (rev/min). Descriptive statistics were also used to describe the mean plus or minus the standard deviation for the VO_2 and MET results obtained from each treadmill used in the study. Correlational statistics were used to determine the degree of relationship between VO_2 and MET results from nonmotorized and motorized treadmills. A t test for correlated means was used to determine if there was a significant difference, alpha < 0.05, when measuring VO_2, in ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, and MET results. The standardized mean effect size is the difference in means divided by the pooled standard deviation (Glass, 1976). The effect size was the chosen tool for summary statistics because it provided both direction and magnitude.

CHAPTER IV

RESULTS

Descriptive statistics for study participants are given in Table 2. The descriptive statistics for the treadmills used in the study are provided in Table 3. These tables include means and standard deviations for participant age (yr), weight (kg), height (cm), and stride cadence (rev/min) and treadmill VO_2 in $ml{\bullet}kg^{-1}{\bullet}min^{-1}$ and MET results.

Table 2

Descriptive Statistics of Study Subjects (n = 30)

Characteristics	Mean $\pm$ SD
Age (yr)	23.2$\pm$2.4
Weight (kg)	69.6$\pm$14.3
Height (cm)	68.1$\pm$4.2
Stride cadence (rev/min)	111.7$\pm$4.1

Note. SD = Standard deviation.

Table 3

Descriptive Statistics of Study Treadmills

Treadmill	Mean ± SD
CW TM	
VO_2	25.9±2.6
METs	7.4±0.7
Jane TM	
VO_2	30.5±2.5
METs	8.7±0.7
Voit TM	
VO_2	29.7±2.7
METs	8.5±0.8

Note. SD = Standard deviation. VO_2 was measured in ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. One MET = 3.5ml $O_2 \cdot kg^{-1} \cdot min^{-1}$.

Correlational statistics were used to determine the degree of relationship between VO_2 and MET results from nonmotorized and motorized treadmills. A t test for correlated means was used to determine if there was a significant difference, alpha < 0.05, when measuring VO_2, in ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, and MET results. A significant correlational coefficient was noted when the CW TM VO_2 and MET results were compared with the Jane TM and Voit TM VO_2 and MET results (Table 4, $r = 0.3$, $p < 0.0001$). These results enabled the researchers to reject the null hypotheses, which stated there would be no significant difference and a high positive correlation between nonmotorized and motorized treadmill VO_2 and MET results.

Effect sizes (ES), such as standardized mean difference (SMD), have been used in recent years in combination with alpha values when identifying the magnitude and significance of research findings (Shaver, 1993; Thomas et al., 1991). Glass (1976) defined the SMD as the difference in means divided by the pooled standard deviation. Cohen (as cited in Thomas, Salazar, & Landers, 1991) used the resultant number to classify the magnitude of the results as small (ES < 0.41), moderate (ES between 4.1 and 0.70), or large (ES > 0.70). A large ES in combination with a statistically significant p value provides the researcher confidence to avoid a Type I error. On the other hand, a small ES in combination

Table 4

Correlational Coefficients and Two-Tailed t-Test Results Between CW TM, Voit TM, and the Jane TM

Treadmills	r	p (2-tail)
CW TM vs. Voit TM		
VO_2	0.3	0.0001
METs	0.3	0.0001
CW TM vs. Jane TM		
VO_2	0.3	0.0001
METs	0.3	0.0001
Voit TM vs. Jane TM		
VO_2	0.7	0.055
METs	0.7	0.054

Note. r = correlation coefficient.

with a statistically significant p value may lead the researcher to a Type I error, possibly, based on a small sample size. In essence, ES is used to estimate the magnitude of research results and is not a function of sample size, as is statistical significance. Therefore, ES was the chosen tool for summary statistics because it provides both direction and magnitude (see Table 5).

Table 5

Standard Mean Difference (SMD) Effect Sizes (ES) for the CW TM, Jane TM, and Voit TM

Treadmills	ES
Jane TM vs. Voit TM [a]	0.31
Jane TM vs. CW TM [a]	1.80
Voit TM vs. CW TM [a]	1.43
Jane TM & Voit TM vs. CW TM [b]	1.62

[a] SD average based on 60 subjects. [b] SD average based on 90 subjects.

CHAPTER V

DISCUSSION

The purpose of this study was to ascertain whether or not walking on a nonmotorized treadmill produced an increase in VO_2 and MET results when compared with walking on a motorized treadmill. Thirty participants were involved in the study. This group was divided into 15 males and 15 females. Each participant completed the exercise protocol as previously outlined. There were no injuries noted during any part of the research study. Instrumentation used in the study included one motorized treadmill, two nonmotorized treadmills, a MET cart, and a metronome. No mechanical problems occurred during any part of the research study.

The underlying goal of most research dealing with fitness enhancement is to find new ways to do just that, enhance a person's fitness level. This was the goal of researchers before and after Astrand and Ryhming (1954) and it was definitely the goal of this research study. This study has answered questions posed by previous researchers, complemented some of their suggestions, and introduced some implications for the future. Many VO_2 prediction equation studies were presented herein, but none were found that dealt with exercise on a nonmotorized treadmill. The significant findings of this study highlight the fact that there need to be VO_2 prediction equations for a nonmotorized treadmill. The importance of VO_2 measurements when looking at fitness levels has been diluted with this study. Some researchers use VO_2 as the single foundation stone upon which all their data rest. For example, Sparrow et al. (1994) used VO_2 to determine the safety of nonmotorized treadmill exercise for heart-failure patients. VO_2 is a key variable when measuring fitness levels, but this researcher concedes that other measurements need to be used in combination with VO_2 when the question of safety is being considered. A suggestion was made by Gamble et al. (1988) that there would be an increase in energy cost of running on a nonmotorized treadmill when compared with motorized treadmill or over-ground running conditions. This study quantified this suggestion by showing that there is, indeed, an increase in energy cost of running on a nonmotorized treadmill when compared with motorized treadmill and over-ground running conditions.

Statistical Overview

Correlational statistics were used to determine the degree of relationship between VO_2 and MET results from nonmotorized and motorized treadmills. A $\underline{t}$ test for correlated means was then used to determine if there was a significant difference, alpha < 0.05, when measuring VO_2, in ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, and MET results for the different treadmills. This study found a low positive correlation

($r = 0.3$) when the CW TM VO_2 and MET results were compared with either the Voit TM or the Jane TM VO_2 and MET results. It also found that the difference between the CW TM and the Voit TM and Jane TM was significant ($p = 0.0001$). The tool chosen for summary statistics was the SMDES. This was used to give magnitude and direction to the correlational and t-test statistical analyses. An ES of 1.62 was calculated for the Jane TM and Voit TM versus the CW TM. This large resultant in combination with an alpha value of 0.0001 enables the researcher to reject the null hypotheses with confidence that a Type I error was not made. The research questions posed in the introduction have been answered. First, it was found that the VO_2 results obtained from the nonmotorized treadmill did significantly differ from those obtained from a motorized treadmill. Secondly, a high positive correlation was not found between the VO_2 results obtained from a nonmotorized treadmill when compared with a motorized treadmill.

Implications for Practice

The results of this study have many implications for future practice. In a rehabilitation setting in which slow, steady aerobic exercise is desired, a nonmotorized treadmill would not be a good choice. With the increases in VO_2 reaching around 30 ml $O_2 \cdot kg \cdot^{-1} ml^{-1}$ (Table 3) for the nonmotorized treadmill, it is easy to see the difficulty a cardiac patient would have maintaining that level of intensity. It must be realized that this VO_2 increase was achieved in only 3 minutes. Exercise programs with the goal of aerobic conditioning would be wise to select another mode for the same reasons as above. Such rapid increases in VO_2 make endurance training very difficult. On the other hand, some types of sprint training may be a more appropriate use for a nonmotorized treadmill. It has been stated that there are no VO_2 prediction equations using a nonmotorized treadmill. This research establishes the need by finding a significant difference between the two types of treadmills. It was noted during the study that the nonmotorized treadmills used were not as sturdy as the motorized treadmill. This was not quantified but is simply an observation made by the researchers and may help with the decision to purchase a nonmotorized treadmill.

Recommendations for Future Research

1. Replicating this study using more than three treadmills.

2. Replicating this study using different populations.

3. Replicating this study looking to correlate VO_2 with other physiological variables such as the respiratory quotient and heart rate.

Conclusion

In summary, the results of this research study show a significant difference in VO_2 and METs measured on a nonmotorized treadmill when compared with a motorized treadmill. These results demonstrate a need for more research in order to develop a VO_2 prediction equation for nonmotorized treadmills. The data support the suggestion by Gamble et al. (1988) that there is an increase in energy cost of running on a nonmotorized treadmill when compared with motorized and over-ground running conditions. Finally, this study has hopefully achieved its goal of providing information that may help enhance public fitness.

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APPENDICES

APPENDIX A

DESCRIPTIVE INFORMATION

Identification number: __________

Date: ____________________

Height (cm): _______________ Weight (kg): _________

Age (yrs): _________________ Sex: ______________

Cadence (rev/min): ___________

Study criteria questions (circle the appropriate answer):

1.	Have you smoked within the past six months?	Y	N
2.	Do you have any cardiac or pulmonary problems?	Y	N
3.	Do you have any orthopedic problems?	Y	N

APPENDIX B

INFORMED CONSENT

Dear Participant:

The purpose of this study is to determine the effects of non-motorized treadmill walking and motorized treadmill walking on oxygen uptake (VO_2) results of males and females, ages 20-30. As a participant, you will be required to walk at a pace of 3 miles per hour and 13% grade for a total exercise time of 9 minutes. The exercise time will be broken up with 3 minute recovery periods. During the study, a pulse oximeter will be used to measure your heart rate and a metabolic cart will be used to measure your oxygen uptake.

From this study you will receive education and any benefits associated with physical exercise.

Participation is completely voluntary, and you have the right to withdraw from the study at any time without penalty. All the data obtained in this study will be held completely confidential.

If you have any questions, you may contact:

Utah State University
Department of Health, Physical Education, and Recreation

Michael S. Wood	**Dr. Lanny J. Nalder**
Primary researcher	**Major professor**
HPER 159	**HPER Dept.**
(801) 755-3216	**(801) 797-3306**

I ______________________, have read the above information and understand it completely, I am willingly consenting to participate in this study.

____
Participant Signature Date

APPENDIX C

MET CART CALIBRATION

"ANALYZER CAL" PROCEDURE

VERS #: IMS-0601-01 NORM : N-1804-4 DATE: 23-FEB-95
NAME : Mike Wood Thesis Cal. ID #: Test Calibration

CAL STAGE

	OBS
FLUSH	20.91
O2 SPAN1	26.00
O2 SPAN2	16.00

CAL VERIFY STAGE

	COR. FACTOR	OBS	PRED	DIFF
CO2 SPAN1(ZERO)	0.230	0.00	0.00	0.00
CO2 SPAN2	1.187	3.99	4.00	0.01
FLUSH		20.90		
O2 SPAN1		25.99	26.00	0.01
O2 SPAN2		15.99	16.00	0.01

VERS #: IMS-0601-01 NORM : N-1804-4 DATE: 23-FEB-95
NAME : Mike Wood Thesis Cal. ID #: Test Calibration

"FLOWMETER CAL" PROCEDURE

TEMP: 24°C REL HUMIDITY: 63% PRES: 656 mmHg
BTPS PRED: 3.30 (Liters) CORRECTION FACTOR: 1.21

STROKE		1	2	3	4	AVG	%PRED	STD DEV
CAL	(——)	2.72	2.73	2.73	2.70	2.72		0.014
VERIFY	(·······)	3.30	3.29	3.30	3.30	3.30	100	0.005