ABSTRACT

Foley, T. S. The effects of the CROSS WALK[R]'s resistive arm poles on the metabolic costs of treadmill walking. MS in Adult Fitness/Cardiac Rehabilitation, 1994, 48pp. (N. Butts)

The recently developed CROSS WALK[R] exercise treadmill incorporates resistive arm poles designed to increase the metabolic costs associated with walking. Twenty-nine healthy men (mean age, 24.2 yr) were recruited to study the physiological effects of utilizing the arm poles during normal treadmill walking at 2, 3, and 4 mph at a 3% grade. Ss walked at each test speed for 5 min with arms and 5 min without arms, achieving steady state HR and VO_2 at each of the 6 stages. The arm poles increased VO_2 ($ml \cdot min^{-1}$) by an average 58% and HR by an average of 32% above normal walking. Using arm poles increased RPE to a much lesser degree (9.1%). Except for RER, the arm pole treatment produced significantly ($p < .01$) higher values for all remaining metabolic variables (V_E, $L \cdot min^{-1}$, kcals, and METs). It was concluded that the CROSS WALK[R]'s arm poles allowed individuals to obtain higher exercise intensity levels during treadmill walking without corresponding increases in perceived cardiovascular strain.

THE EFFECTS OF THE CROSS WALK[R]'S RESISTIVE ARM POLES ON THE METABOLIC COSTS OF TREADMILL WALKING

A THESIS PRESENTED

TO

THE GRADUATE FACULTY

UNIVERSITY OF WISCONSIN-LA CROSSE

IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

MASTER OF SCIENCE DEGREE

BY

THOMAS SHANE FOLEY

DECEMBER 1994

COLLEGE OF HEALTH, PHYSICAL EDUCATION, AND RECREATION
UNIVERSITY OF WISCONSIN-LA CROSSE

THESIS FINAL ORAL DEFENSE FORM

Candidate: Thomas Shane Foley

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Cardiac Rehabilitation / Adult Fitness

The Candidate has successfully completed his final oral examination.

Thesis Committee Chairperson Signature	5/13/94 Date
William A. Floyd Thesis Committee Member Signature	5/13/94 Date
Thesis Committee Member Signature	5-13-94 Date

This thesis is approved by the College of Health, Physical Education, and Recreation.

Gary T. Gilmore Associate Dean, College of Health, Physical Education, and Recreation	5-25-94 Date
Dean of UW-L Graduate Studies	1 June 1994 Date

ACKNOWLEDGMENTS

I would like to thank my family and friends for their patience and support during the completion of my thesis and Masters Degree. This paper is dedicated to my parents who have always been by my side with advice, knowledge, and love, especially to my father who passed away during the completion of this paper. His words of wisdom and constant encouragement to always strive for my best will be with me forever.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Background

The importance of exercise has received increased attention as many of its health benefits become realized. For example, increased cardiovascular fitness is currently linked with lowering the risk for coronary artery disease, reducing resting systolic and diastolic blood pressure levels, and improving regulation of diabetes by aiding in lowering blood sugar levels (ACSM, 1991). In order for enhancements of health and cardiorespiratory fitness to be realized, the ACSM (1991) recommends exercise programs to include three to five weekly sessions of any activity using rhythmic movements of large muscle groups maintained at high enough training intensities (i.e., 40 to 85% of maximal aerobic capacity) for 15 to 60 minutes.

Walking as an aerobic exercise modality provides many benefits. It is both affordable and accessible to a large population. According to Porcari et al. (1987) a high percentage of people (81% of males and 86% of females) can attain aerobic training levels while walking. Although normal walking training programs have been shown to increase aerobic power (VO_2max) by 15% during leg ergometry (Stamford, Cuddihee, Moffatt, & Rowland, 1978), arm ergometer testing on walking trained subjects shows only minimal increases in VO_2max (Franklin, Vander, Wrisley, & Rubenfire, 1983; Lewis, Thompson, & Areskog, 1980; Stamford et al., 1978). According to Franklin (1989), leg training alone, such as walking and running programs, result in a limited transfer of benefits to the upper body (i.e., training is generally limb specific).

Many modes of exercise have been designed to incorporate upper body exercise with walking, thus increasing the total exercise intensity compared to walking alone. The use of Exerstrider poles have been shown to increase walking intensity 12% compared to walking without the poles (Babyak, VanHeest, & Rodgers, 1991). Walking while carrying hand weights has been shown to increase oxygen consumption (VO_2) at a given pace when compared to unweighted walking (Auble, Schwartz, & Robertson, 1987; Graves, Pollock, Montain, Jackson, & O'Keefe, 1987; Zarandona, Nelson, Conlee, & Fisher, 1986).

Gutin, Ang, and Torrley (1988) provide evidence suggesting that when the arms are exercised along with the legs, a larger total metabolic workload can be maintained by subjects even though no changes occur in either cardiovascular strain or rate of perceived exertion. For example, one study found that walking with hand weights at 4 mph was comparable in intensity to running at 5 mph (Miller & Stamford, 1987). This benefit is especially valuable to persons who have difficulty maintaining faster speeds. Combined arm and leg exercise is also more readily tolerated than arm or leg exercise alone (Stenberg, Astrand, Ekblom, Royce, & Saltin, 1967) which might increase the likelihood of training adherence. Finally, inclusion of upper body work in training repertoire leads to increased benefits to persons who use their upper body regularly in daily activities.

The recently developed CROSS WALK[R] (Proform[R] Inc., Logan, UT) treadmill combines arm exercise with the versatility of a walking exercise regimen. Resistive arm poles attached to the CROSS WALK^R are designed to increase the metabolic cost of normal treadmill walking. This new design provides several advantages over the popular practice of using hand weights while walking. The isometric contractions involved in holding hand weights have been associated with increases in systolic and diastolic blood pressures (Abadie, 1990) which is a contraindication for exercise in hypertensive populations (Graves, Sagiv, Pollock, & Miltenberger, 1988). Increased loads associated with hand weights have also been linked to injury of the knee, ankle, and foot due to the increased stress level (Pollock, Carroll, & Graves, 1991).

The CROSS WALK^R provides a potential way of increasing intensity without the stresses associated with hand weights. Theoretically this would allow slower walking speeds for a given exercise intensity, thus reducing the chance of injury (Carroll et al., 1992). The correlation between faster treadmill speeds and increased incidence of injury (Carroll et al., 1992) provides an illustrative example of possible CROSS WALK^R benefits. The proposed increased intensity level directed to the upper body by the CROSS WALK^R's arm poles could allow for slower treadmill speeds than in normal treadmill walking while maintaining the same overall intensity level.

Need for the Study

The CROSS WALK^R provides the possibility of many exercise benefits. Due to the recent development of this exercise modality, no research has been conducted to assess its proposed advantages. This research will provide evidence concerning the effectiveness of the CROSS WALK^R in increasing exercise intensity compared to normal treadmill walking. Results of this testing could be especially useful to populations who might benefit from the unique training alternative the CROSS WALK^R provides. Specifically, aerobic exercise might be potentially obtained at slower walking speed, thus, benefiting persons with orthopedic problems, arthritics, or those who dislike running in general.

Purpose

The purpose of this study was to compare the physiological responses of treadmill walking with and without incorporation of the CROSS WALK^R's arm poles at various speeds in men.

Null Hypothesis

There will be no significant differences in various physiological responses (e.g., heart rate, VO_2, and kcal) using the CROSS WALK^R's arm poles compared to normal treadmill walking at similar speeds.

Assumptions

This study had the following assumptions:

1. Techniques used for assessment of heart rate, VO_2, METs, kcals, and respiratory exchange ratios were assumed to be accurate.
2. Each subject's health and fitness levels were assumed to remain constant for all performed tests.
3. Subjects were assumed to be normal, healthy adult males.

Delimitations

This study had the following delimitations:

1. Subjects used in this study were limited to males between 18 and 40 years of age.
2. Subjects with known contraindications for exercise or exercise testing (i.e., heart problems, EKG abnormalities, and respiratory disease) were not allowed to participate.

Limitations:

The following limitations were recognized:

1. Subjects for this study were volunteers, thus a nonrandom sample was used.
2. Laboratory climate conditions (i.e., temperature, relative humidity, and barometric pressure) were regulated by the building's ventilation system and environmental variables and, therefore, were not controlled by the researcher.
3. Due to the stress placed on the CROSS WALK[R] during testing, the tension of the resistive arm poles was found to decrease dramatically during exercise. Therefore, the amount arm pole tension varied during each testing session, as well as between testing sessions, could only be controlled by calibrating the tension before each testing session as well as manually holding the tension screw in place during the exercise bouts.

Definition of Terms

The following terms were used in this study:

CROSS WALK[R] - a commercial exercise treadmill produced by Proform[R] Inc., Logan, UT. The CROSS WALK[R] featured a 2.58 m, 30 cm wide belt, LED display of elapsed time, mileage, speed (mph), and calories burned, a pulse sensor for measuring heart rate on the ear lobe, and resistive arm poles attached to the front of the treadmill. This is the exercise modality that was tested in this study.

Oxygen Consumption (VO_2) - the volume of oxygen consumed per minute which is accepted as reliable measures of exercise cost. Oxygen consumption values were obtained by a Q-Plex gas analyzer using open circuit spirometry which was calibrated before each test and reported both in relative ($ml \cdot kg^{-1} \cdot min^{-1}$) and absolute ($l \cdot min^{-1}$) terms.

Respiratory Exchange Ratio (RER) - a mathematical ratio of oxygen consumption to carbon dioxide production ($mlO_2 \cdot min^{-1} / ml\ CO_2 \cdot min^{-1}$) which is used as an indicator of the percentage of carbohydrates and fats being used as energy sources. Normal ranges of RER are from 0.7, indicating consumption of fat, to 1.0, indicating the sole use of carbohydrates as the energy source. The Q-Plex measures "nonprotein RER", which neglects any contribution of proteins to energy production. Since the use of protein (RER = 0.8) as an energy source is so slow during exercise, RER and nonprotein RER are essentially equivalent (ACSM, 1991). Values of RER were obtained from the Q-Plex gas analyzer using open circuit spirometry.

Steady-State Exercise - each workload of this study was performed for long enough duration as to allow each subject to reach a plateau or "steady state" for heart rate and VO_2. Steady state was considered to be reached if there was less than a 4 beat per minute change in heart rate for two consecutive minutes at the same workload and less than 1.0 $ml \cdot kg^{-1} \cdot min^{-1}$ change in VO_2. Every workload in this study was carried out for at least five minutes to ensure steady state was reached.

METs - an indicator of exercise intensity. One MET is defined as 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ which is accepted as the approximate oxygen consumption level at rest.

Kilocalories (kcals) - a measure of energy expenditure usually in relation to cumulative energy expenditure during exercise. Kilocalories were measured by open circuit spirometry using a Q-Plex gas analyzer. Kilocalories are related to exercise intensity by the consumption of oxygen (VO_2). The number of kcals burned for every liter of oxygen varies depending on which substrate the body is using for fuel. Five kcals are burned for every liter of oxygen when carbohydrates are being used exclusively (RER = 1.0). Conversely, when fat is the energy substrate (RER = 0.7), 4.4 kcals are burned for every liter of O_2. Thus, the Q-Plex calculates kcals using both level of oxygen consumption and nonprotein RER.

Rate of Perceived Exertion (RPE) - is a subjective measure of exercise intensity. The scale developed by Borg (1962) was originally based upon 10 second heart rate values ranging from 6 (very, very light) to 20 (very, very hard). Subjects in this study were asked their rate of perceived exertion during the fourth minute of every work stage.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

In order to more effectively assess potential advantages of the CROSS WALK^R, it is necessary to understand the characteristics of walking as an exercise modality. This will provide reference for results of this study. In addition, thorough knowledge of existing exercise modalities which incorporate the arms will provide useful comparisons for any intensity increases found with use of the CROSS WALK^R's resistive arm poles. This chapter presents an overview of literature relating to benefits and metabolic costs of walking with and without incorporation of upper body work.

Walking as an Exercise Form

The role exercise plays in health is becoming increasingly clear. A sedentary life style is currently linked with increased risk for coronary artery disease (ACSM, 1991). In addition, aerobic training programs have been shown to reduce resting systolic and diastolic blood pressure, increase the workload at which angina occurs in cardiac rehabilitation patients, and improve regulation of diabetes by aiding in the lowering of blood sugar levels (ACSM, 1991). Table 1 summarizes cardiovascular and other adaptive responses associated with regular physical activity.

Table 1. Mechanisms by which physical activity may reduce the occurrence or severity of coronary heart disease[a].

Increase	Decrease
Heart muscle efficiency	Serum triglycerides
Red blood cell mass	Serum cholesterol
Blood volume	Obesity
Tolerance to stress	Blood pressure
Coronary collateral	"Strain" associated with
Prudent living habits	

[a]Adapted from Fardy, Yanowitz, & Wilson (1988, p.13).

Aerobic exercise training programs bring about these favorable increases in cardiovascular fitness if an individual exercises for at least 15 minutes three times per week (ACSM, 1991). To be considered aerobic, an activity must be able to be carried out at an intensity equal to or greater than 40 to 85% of an individual's VO_2max. This is often approximated using 55 to 90% of the individual's theoretical maximal heart rate of 220 minus age (ACSM, 1991).

Walking has been shown to be an adequate stimulus for aerobic levels of training for 81% of males and 86% of females (Porcari et al., 1987). Walking has several other advantages as an exercise modality. Since walking can be carried out in virtually any environment, both indoors and outside, requires no exceptional skill, and is essentially cost-free, it is an extremely accessible exercise form. The low impact nature of walking makes it the exercise of choice for people with arthritis or other lower extremity problems.

Treadmill walking has even been shown to utilize a larger percent of fat expenditure than cycling or rower ergometry at similar heart rates (Thomas, Feiock, & Araujo, 1989). Walking, however, lends little, if any, benefit to upper body conditioning.

<u>Metabolic Cost of Walking</u>

The energy cost of walking has been measured and estimated by many authors. In the formation of appropriate prediction equations, authors have tended to break down the total work performed into various components. As early as 1959, Bobbert attempted to determine if the development of a general formula for analysis of energy cost of treadmill walking was feasible. Such an equation could be used in physiological experiments and functional tests and, "very few attempts have been made to derive a general formula relating energy expenditure to speed and gradient" (Bobbert, 1959, p. 1015). Bobbert discounted the use of a road constant employed in previous research. Any formula derived by Bobbert's research would be only an approximate estimate since previous literature had demonstrated energy expenditure in walking was affected by many variables such as age, sex, training, shoe weight, and body composition. Bobbert agreed with other authors in that the most important component was body weight, thus, he dealt in terms of relative energy expenditure (i.e., $kcal \cdot kg^{-1} \cdot min^{-1}$) in order to equalize differences among subjects. Bobbert's study conducted on 10 young, healthy adult males produced the following equation:

$$log(E_W) = 1.4272 + (0.004591 \cdot speed) + (0.024487 \cdot grade) + (0.0002658 \cdot speed \cdot grade)$$

where E_W is energy expenditure in Kcal• kg^{-1}• min^{-1}, *speed* is treadmill belt velocity expressed in m• min^{-1}, and *grade* is treadmill gradation in degrees.

Since the early work of Bobbert (1959), other researchers have developed prediction equations including additional independent variables. The following is an example from Workman and Armstrong (1963):

$$VO_2 = P_W \cdot K_S + 3.05 \cdot grade \cdot speed$$

where P_W is an individual constant dependent on subject height and weight, K_S is a speed constant based on treadmill or ground speed, *grade* is treadmill gradation expressed as a fraction (grade % /100%), and *speed* is treadmill belt velocity expressed as mph ($1.0 \leq speed \leq 4.0$).

The current equation used by the American College of Sports Medicine (1991) is basically a refinement of similar equations to Bobbert's (1959). The ACSM equation for treadmill walking was adapted from horizontal walking research conducted by Dill (1965) and a study on the oxygen cost of vertical work during stepping (Balke & Ware, cited in Montoye, Ayen, Nagle, & Howley, 1985). The formula is based on the empirical physiological costs associated with each component of walking: (1) horizontal component, (2) vertical component, and (3) resting metabolic rate (Montoye et al., 1985). Thus relative VO_2 can be approximated between 2.0 and 3.7 mph by using only speed and grade as independent variables (ACSM, 1991):

$VO_2(mlO_2 \cdot kg^{-1} \cdot min^{-1}) =$

(horizontal component)	$speed \times 0.1 (mlO_2 \cdot kg^{-1} \cdot min^{-1}) \cdot (m \cdot min^{-1})^{-1}$
(vertical component)	$+ grade \times speed \cdot 1.8 (mlO2 \cdot kg^{-1} \cdot min^{-1}) \cdot (m \cdot min^{-1})^{-1}$
(resting component)	$+ 3.5 (mlO_2 \cdot kg^{-1} \cdot min^{-1})$

where speed is expressed in m• min^{-1} and grade is expressed as a fraction (grade % / 100%).

The ACSM equation is based on the consensus in the literature that relative energy expenditure could be closely approximated using only treadmill grade and walking speed as variables. Other factors such as steps per minute, height, and stride length, could not be found to contribute to an accurate general formula. In addition, the incorporation of subject dependent variables such as height and weight increase the complexity of a formula while not permitting calculations to be performed without a specific reference to an individual. The ACSM formula has become widely used, notably in the basic test for ACSM certification of exercise professionals (Montoye et al., 1985).

Smith, Borysyk, Dressendorfer, Gordon, and Timmis (1984) compared predicted energy expenditure from the ACSM equation against a population of coronary heart diseased patients and found the estimated value markedly overestimated actual VO_2. Additionally, the ACSM formula underestimated VO_2 by about 1 ml•kg^{-1}•min^{-1} for grade treadmill walking when compared to Balke and Ware's 1959 equation (Montoye et al., 1985).

These discrepancies prompted a large validation study in 1985 (Montoye et al.). These researchers tested over 1000 healthy male subjects, ranging from 10 to 59 years of age, walking at 3 mph over a range of treadmill grades. Montoye and associates found that the ACSM equation "estimated remarkably well" (1985, p. 641) their subjects' actual oxygen consumption over most age ranges and treadmill grades. Two main discrepancies, however, were detected.

First, for subjects under 18, the ACSM equation was found to underestimate actual VO_2 for all grades, and the younger the age, the greater the error. Montoye et al. (1985) credited this discrepancy to the fact that only males 18 years or older were used in developing the formula. Another contributing factor is that inefficiency (high VO_2 requirement) in children is common and decreases with increasing age, presumably due to growth (Robinson, cited in Montoye et al., 1985). Second, the ACSM underestimated metabolic cost of walking for horizontal and 3% grade walking which was common across age groups.

These two discrepancies persuaded the ACSM (1991) to include the following revision with their metabolic estimation equation for walking:

> ... the formula is more accurate in estimating VO_2 when the participant is walking up a grade than on the level. Underestimates of 15 to 20% are expected with level walking, and 5 to 8% with walking up a 3% grade. Also, children are less efficient in walking and running than adults. The walking formula underestimates the oxygen requirement by approximately 0.5 $ml \cdot kg^{-1} \cdot min^{-1}$ for each year of age below the age of 18 years. (p. 289)

The ACSM equation is otherwise generally accepted for walking speeds between 1.9 and 3.7 mph.

Transfer of Training Effects Between Limbs

It has been commonly thought that leg or arm training would provide a transfer of effects to the untrained limbs (Franklin, 1989). This is evidenced by the practice of rehabilitation of injured limbs by exercising the healthy limbs (Franklin, 1989). Recent research, however, has found little support for the transfer of training effects between arms and legs. Furthermore, arm training is not as effective as leg training in eliciting increases in overall cardiovascular fitness (Franklin, 1989).

Thompson, Cullinane, Lazarus, and Carleton (1981) conducted a 10-week training study comparing effects of leg and arm conditioning. Arm trained subjects had a 19% increase in VO_2max as measured by an arm ergometry exercise test. Leg trained subjects showed a similar increase of 15% in VO_2max as measured by a leg ergometer exercise test. Neither group, however, was found to have any significant VO_2max increases when measured on the opposite testing modality. Lewis et al. (1980) found that leg training subjects increased VO_2max by 15% when measured by leg ergometry but only showed a 9% increase on arm ergometry tests. Clausen, Trap-Jensen, and Lassen (1970) found that leg training decreased resting heart rate values whereas arm training did not elicit this response. Conversely, arm training resulted in bradycardia at submaximal workloads in arm ergometry but not in leg ergometry.

The research seems to suggest that there is minimal, or at least a reduced, transfer of training effects between limbs. In addition, arm training and leg training elicit different physiological responses. These findings appear to discount the practice of emphasizing leg training alone (Franklin, 1989) during rehabilitation or in order to gain maximal aerobic training benefits. Indeed, these results suggest that additional limb specific training is necessary to maximize the conditioning response since the observed cross trained improvements in arm VO_2max was much lower than that achieved for arm training alone.

Benefits of Combined Upper and Lower Limb Exercise

Due to the minimal transfer of training effects between limbs, a combined upper and lower body workout is important. Arm training and testing are important in individuals who use arm work in their daily routine (Franklin et al., 1983). Combined arm and leg training is also linked with enhancing weight control, cardiovascular rehabilitation, and aerobic conditioning programs (Gutin et al., 1988). Stenberg et al. (1967) found combined arm and leg training was more readily tolerated than arm or leg training alone. Gutin et al. (1988) determined that combined arm and leg training allows a greater metabolic load to be maintained with no increases in overall cardiovascular or subjective (RPE) strain. Similar results lead Mostardi, Gandee, and Norris (1981) to conclude that since combined arm and leg training places less physical stress on the heart while delivering similar overall increases in aerobic capacity, it is an extremely beneficial and favorable exercise modality for cardiac rehabilitation patients.

Modalities for Increasing the Metabolic Cost of Walking

The attempt to increase the metabolic cost of walking has received considerable emphasis in the literature. Although no studies have been conducted on the effects of the CROSS WALK[R]'s upper body exercise on walking, studies on various other modifications to walking provide valuable reference for this study. Studies involving hand weights, wrist weights, and ankle weights were reviewed in order to provide comparisons for results of this investigation.

In a study of the effects of hand weights on five male and five female subjects, Francis and Hoobler (1986) had subjects walk at 3.0 and 3.5 mph with no grade using hand weights of 0.91 and 1.81 kg (2 and 4 lb). Nonsignificant increases in VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) of approximately 8% at 3.0 mph and 6% at 3.5 mph were found. Running speeds (5.0 mph) were required to produce significant increases in relative VO_2 with hand weights. These results led the authors to conclude, "Although walking with light hand weights have become popular, results of this study indicate that aerobic benefits may be marginal at best" (Francis & Hoobler, 1986, p. 1002).

Another 1986 study by Maud, Stokes, and Stokes found similar nonsignificant changes in VO_2 and HR when subjects walked with 3 and 4 lb hand weights. In addition to trials with normal arm swings, as conducted by Francis and Hoobler (1986), Maud and associates added the treatment of vigorous arm swings where subjects pumped the weights up to shoulder height. These vigorous arm swings produced significant increases in the metabolic cost of walking.

A third 1986 study by Zarandona and colleagues essentially duplicated the results of Maud and associates (1986). These authors found that significant increases in walking VO_2 using hand weights were only attainable if the subjects employed vigorous arm swings.

Miller and Stamford (1987) assessed the effect of ankle and hand weights on walking exercise cost. These authors found an average VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) increase of approximately 18% for ankle weights and 29% for hand weights over the testing speeds of 2, 3, and 4 mph. When the two types of weights were used simultaneously, VO_2 increased by over 40%. In order to show the applicability of these results to real world situations the authors pointed out that walking with both hand and ankle weights at 4 mph was approximately the same as running at 5 mph.

Auble and colleagues (1987) looked at the effect of pump height on normal walking. The exaggerated height of their subjects' arm pumping motions ranged from raising the weight to shoulder level to raising the weight considerably above the head. The effect of the 1, 2, and 3 lb weights over walking speeds from 2.5 to 4.0 mph was considerably larger than results reported by previous authors. Weighted walking increased VO_2 over normal walking from 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ (13%) to 25.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (155%). These large increases allowed even their subjects with excellent levels of aerobic fitness to reach training intensity levels while walking.

Owens, Al-Ahmed, and Moffatt (1989) felt that although employing a vigorous arm swing with the use of hand weights had been shown to significantly increase the exercise cost of walking, this method was not desirable. These authors felt that the exaggerated arm swing might disrupt the normal kinematics of walking, lead to early fatigue of smaller muscle groups of the arm, and place excessive stress on the shoulder. These negative effects would be magnified if the activity were carried out for 15 to 60 minute exercise sessions three to four times a week. Thus, Owens and colleagues set out to determine if a weight threshold existed which might effectively increase VO_2 during walking while maintaining natural arm movements. Using weights of 1, 3, and 5 lb and walking speeds of 3 and 4 mph, they found no significant enhancements to the metabolic cost of walking. They concluded that unless vigorous arm movements were used, weights of 5 lb or less contribute little to augmenting walking intensity. These authors suggested that merely increasing walking speed was a much more effective and safer method than the use of hand weights in providing larger energy expenditures.

Graves and associates (1987) uncovered yet another problem with the use of hand weights, that being an undesirable elevation of diastolic blood pressure (DBP). This elevation of DBP may be contraindicated for individuals with hypertension or coronary artery disease. This finding prompted Abadie (1990) to investigate the use of wrist weights as a possible alternative, since the isometric contractions associated with griping the hand weight would be eliminated. By eliminating the isometric contraction, wrist weight would reduce the pressor response associ[illegible] with holding the hand held weights and, thus decrease or eliminate the elevation in DBP. In order to ensure significant increases in VO_2, Abadie's subjects utilized vigorous arm swings. Both wrist and hand weights showed significant increases in VO_2 over normal walking at 3 mph at 8% grade. In addition, hand weights produced significantly higher results than the wrist weights. The wrist weights, however, showed no increase in DBP as the hand weight treatments produced. The author concluded that wrist weights may be used to eliminate the undesirable elevations in DBP seen with hand weights.

Summary

Walking is an easily mastered, inexpensive, and accessible exercise modality. The addition of upper body exercise provides many advantages. First, the ability of a lower body exercise to provide a transfer of benefits to the upper body, such as in rehabilitation, is minimal at best. Second, exercise of the arms will help individuals to increase upper body strength and conditioning, aiding in work related duties or tasks of daily living. Third, by assigning some of the total metabolic load to the upper body, a larger overall exercise cost can be maintained with little or no increase in RPE. Thus, through these higher intensity workouts, greater improvements in cardiovascular fitness may occur with training.

The application of these principals to walking has produced mixed results. Large increases in VO_2 have been demonstrated using hand weights while walking, however, controversial exaggerated arm pumping is necessary to elicit the desired augmentation of work intensity. Hand weights are associated with elevation of DBP and may cause undue stress to the arms and shoulders. Although wrist and ankle weights provide solutions to problems presented by hand weights, these two walking treatments produce much smaller enhancements in exercise cost.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The experimental design for this research was extremely involved for two main reasons. First, this experiment represents the first research on the CROSS WALK^{R} treadmill. The difficulty of walking with the upper body arm attachments was not known. Thus, an extensive pilot study was necessary to determine which speeds and elevations would be readily tolerated by average individuals. Second, the recent development of the CROSS WALK^{R} had allowed little or no feedback from consumer usage to determine the problems associated with this new exercise modality. This became evident during the pilot study: the CROSS WALK^{R}'s speedometer was inaccurate and its LED readout fluctuated rapidly making actual speed determination virtually impossible.

These additional challenges made the development of appropriate workloads and measurement of speed difficult. Only after adapting testing conditions to these limitations could the actual subject recruitment and testing sessions begin.

Subjects

Twenty-nine male subjects between 18 and 41 years of age were recruited from the University of Wisconsin-La Crosse campus population. The sample obtained was nonrandom due to the voluntary nature of participation.

Each subject filled out an informed consent form prior to participation (see Appendix A). Subjects were given an overview of testing procedures, goals of the research, and data that would be obtained. Subjects were informed that they could withdraw from the study at any time.

Experimental Design

Pilot Study

The goal of this research was to compare physiological responses of walking on the CROSS WALK^R while using its resistive arm poles with normal treadmill walking at various workloads (i.e., treadmill speeds and elevations). Since this study represents the first research on the CROSS WALK^R, the relative increases in intensity found by the addition of the arm work while walking were unknown. During the pilot study 12 subjects were tested using various combinations of speed and elevation to determine which workloads were appropriate and would be able to be completed by the majority of subjects.

Results of the pilot study indicated that many of the subjects could not complete 5-minute workloads at 5 mph and 3% grade while incorporating the CROSS WALK^R's upper body load. Incorporation of the arm poles at a walking speeds of 4 mph at a 10% grade was also not tolerated by the majority of subjects.

In order to provide an understanding of the relationship between treadmill walking with and without the resistive arm exercise, three speeds were deemed necessary to determine the effect of adding arm work at various speeds. From the pilot study, 4 mph at the CROSS WALK[R]'s lowest elevation (3%) was chosen as the highest workload, since all subjects in the pilot study could complete this speed and elevation with incorporation of the resistive arm poles for at least 5 minutes.

<u>Protocol</u>

Speeds of 2, 3, and 4 mph were chosen for this study to represent the range of walking speeds for most individuals. Walking, not running, was the emphasis of this study as it is walkers who might particularly benefit from increased intensity levels produced by use of the CROSS WALK[R]'s upper body exercise. Three speeds were used to allow insight into the interaction of the upper body exercise with various treadmill speeds.

An elevation of 3% was chosen for all stages of this study for two reasons. First, this elevation was readily tolerated at 4 mph by subjects in the pilot study, while higher elevations were too difficult for many of the subjects. Second, 3% grade is the CROSS WALK[R]'s lowest elevation. It was felt that the choice of exercise workloads that would be typical of normal home use would provide the most directly applicable results to the general public.

In order to achieve steady state at each workload 5-minute stages were used. All subjects were exposed to the speeds in increasing order (i.e., 2, 3, and 4 mph). This was done to prevent artificial heart rate and metabolic cost elevations which might result from performing one of the easiest workloads immediately following one of the hardest. Although the order of the speeds was the same for all subjects, the order of incorporation of the CROSS WALK[R]'s arm poles was randomized for each speed for each subject. For example, some subjects' first stage was 2 mph without incorporation of the resistive upper body loads, and for others the first stage was 2 mph with the use of the CROSS WALK[R]'s resistive poles.

Testing Procedure

Practice Session

Subjects reported to the Human Performance Laboratory at the University of Wisconsin-La Crosse. Although no specific requirements were placed on attire, use of tennis shoes and appropriate exercise clothing was encouraged. Subjects were instructed to refrain from eating or caffeine intake 3 hours prior to testing. Two testing dates were scheduled with each subject, one for a practice session and one for the actual testing.

During the first appointment, subjects were given an oral overview of the testing protocol, measurements to be taken, the risks associated with submaximal exercise testing, and told that they were participating on a volunteer basis and could withdraw from testing at any time. Subjects were given time to ask questions and then signed the informed consent form (see Appendix A).

Subjects were instructed on the use of Borg's (1962) rate of perceived exertion scale (RPE). They were informed that this scale was to be used as a subjective measure of exercise intensity. Subjects were instructed to indicate when the researcher pointed to the number on the RPE scale that corresponded to their perception of their overall work intensity for a given workload. A nod of the head was used as the indicator since the subjects' mouths were attached to the gas analyzer and their hands would be gripping the CROSS WALK[R]'s arm poles.

Subjects were next instructed on use of the CROSS WALK[R] treadmill. After participants became familiar with walking on the CROSS WALK[R] they practiced using the resistive arm poles at all the testing speeds. Subjects were encouraged to find a comfortable stride length at each speed. The only restriction placed upon arm use was to keep the same cadence as their legs, moving the opposite arm and leg together which simulates the natural walking arm swing rhythm.

Testing Session

During the second meeting, subjects were weighed to the nearest kilogram on a Health-O-Meter and their height was measured to the nearest centimeter. The protocol for each subject was determined by random selection for arm use at each speed. Subjects were fitted with a head gear for open circuit spirometry and connected to the Q-Plex gas analyzer. The Q-Plex was calibrated using standardized volumes and gas mixtures prior to each test.

Resitive Arm Pole Tension

The CROSS WALK[R]'s arm poles were tightened to maximal tension and calibrated using a tension gauge prior to each subject's exercise bout. The tension screw was found to loosen during each test so it was monitored and adjusted, if necessary, to increase consistency during each test as well as between testing sessions. Since the CROSS WALK[R] tension control consisted of only one screw for both poles, there was no way to control tension of one pole independently of the other. This resulted in a right pole tension consistently more than 30% less when compared to the left side. Since it was the intention of this study to assess the benefits of the CROSS WALK^{R} in relation to what a typical user might expect, and not to study the effects varying arm tensions, the arm resistance discrepancies were accepted as unavoidable and included as part of the error in this research.

Treadmill Speed

The speedometer provided on the CROSS WALK^{R} was found to be inaccurate. The speedometer fluctuated under the weight of the subjects' steps and the display consistently underestimated actual treadmill belt velocity by approximately 10% at all speeds. To correct for this problem, accurate treadmill speed was determined by measuring the time for 20 revolutions and converting to miles per hour. A mark was attached to the treadmill belt to assist in counting revolutions. This was performed a minimum of two times during each stage to ensure belt speed did not fluctuate by more than 0.1 mph from the target speed. In addition, belt speed for any given subject did not differ between the arm pole and no arm pole conditions at a given speed by more than 0.1 mph.

Measurements Taken During Testing

The VO_2, METs, kcal, RER, and V_E were monitored continuously and converted to minute values by a Q-Plex gas analyzer (Quinton Inc., Seattle, WA) using open circuit spirometry. The Q-Plex gas analyzer was calibrated prior to each testing session using standardized gas mixtures of known concentration previously determined by the micro-Scholander technique. The flow meter volume was calibrated using a 3.002 L syringe pump at various flow rates. Heart rates were taken during the last 15 seconds of every minute using UNIQ-CIC (Computer Instruments Corporation, Hemstead, NY) heart rate monitors. Subjects reported rate of perceived exertion once during the 4th minute of each stage.

No data obtained during the first 2 minutes of any stage were used. This was done to better ensure that values indicative of a steady state were chosen for analysis. From the final 3 minutes of each stage, the full minute value for VO_2 which best represented steady state was chosen. Steady state was considered to be reached if there was less than a 4 beat per minute change in heart rate for two consecutive minutes at the same workload and less than 1.0 $ml \cdot kg^{-1} \cdot min^{-1}$ change in VO_2. Data for kcals, METs, V_E and heart rate were obtained from the corresponding minute.

Standard descriptive techniques were computed for subject characteristics and all metabolic data. Paired t tests were used to determine differences between walking alone and walking while using the upper body exercise poles at each speed. This was carried out for absolute VO_2, relative VO_2, kcals, METs, V_E, heart rate, RPE, and RER. Comparisons were performed for each speed.

CHAPTER IV

RESULTS and DISCUSSION

Introduction

The results of this study were analyzed comparing various physiological variables during normal walking to walking with the upper body loads. The data were also compared to predicted values using the ACSM metabolic equations. Finally, the augmentation provided by the CROSS WALK^R to normal walking was contrasted with other exercise modes incorporating the upper body with walking.

Results

The 29 subjects ranged in age from 18 to 40 and their physical characteristics are presented in Table 2. The subjects' fitness levels ranged from moderately active to competitive college athletes.

Table 2. Subject characteristics (n = 29).

Variable	Mean
age (yr)	24.2 1.0*
height (cm)	179.8 0.4
weight (kg)	78.6 1.9

* = Standard error of the mean

Comparisons between actual VO_2 for normal treadmill walking at a 3% grade (i.e., without arms) and predicted VO_2 from the ACSM (1991) equation for walking are listed in Table 3. Although the actual VO_2 values were similar to the predicted values at 2 and 3 mph, the ACSM equation underpredicted VO_2 by approximately 20% at 4 mph. The predicted ACSM values were significantly ($p < .0001$) lower than the actual VO_2 at all three test speeds.

Table 3. Actual and predicted VO_2 for treadmill walking at 3% grade.

	2 mph	3 mph	4 mph
ACSM	11.8*	15.9*	20.0*
Actual	12.7	16.8	24.0

* = $p < .001$ between ACSM and actual values

The physiological responses to walking with and without use of the arm loads are summarized in Table 4. Addition of the CROSS WALK[R]'s resistive arm load resulted in significant ($p < .0001$) increases in VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) for all three test speeds (i.e., 2, 3, and 4 mph) compared with normal treadmill walking. The utilization of the arm poles increased energy expenditure ($ml \cdot kg^{-1} \cdot min^{-1}$) by approximately 60, 62, and 49% for 2, 3, and 4 mph, respectively. This augmentation corresponded to increases in MET levels of 2.2, 3.0, and 3.4 METs at 2, 3, and 4 mph, respectively. As expected, the arm work enhanced exercise costs were also significantly ($p < .0001$) higher than the ACSM (1991) predicted values for normal walking at 3% grade at all the test speeds.

Table 4. Physiological effect of treadmill walking with and without arm work at 2, 3, and 4 mph at 3% grade.

	2 mph			3 mph			4 mph		
	without	with	change	without	with	change	without	with	change
VE (L•min^{-1})	26.6 *	38.3	43.8%	33.3	50.1	50.6%	46.6	70.8	51.9%
	0.9 **	1.0		1.0	1.5		1.6	2.2	
VO2 (L•min^{-1})	1.0	1.6	59.3%	1.32	2.13	61.1%	1.89	2.8	48.2%
	0.03	0.04		0.04	0.05		0.05	0.07	
VO2 (ml•kg^{-1}•min^{-1})	12.7	20.4	60.5%	16.8	27.2	62.4%	24	35.8	49.4%
	0.2	0.4		0.2	0.6		0.3	0.7	
METs	3.63	5.83	60.4%	4.79	7.78	62.2%	6.85	10.24	49.5%
	0.06	0.1		0.07	0.17		0.1	0.2	
RER	0.82	0.86	3.7%	0.86	0.87	1.6%	0.88	0.96	9.7%
	0.03	0.01		0.01	0.01		0.01	0.03	
Kcal	4.89	7.81	59.5%	6.43	10.46	62.8%	9.27	13.97	50.7%
	0.15	0.18		0.19	0.25		0.25	0.33	
HR (b•min^{-1})	93.1	110	18.2%	103	127.3	23.6%	122.3	151.2	23.6%
	2.2	2.4		2.2	2.8		2.5	2.9	
RPE	7.3	8.0	9.9%	9.7	10.5	8.2%	11.9	13.0	9.3%
	0.3	0.3		0.3	0.4		0.4	0.4	

* = mean, ** = standard error of mean

Incorporation of the arm work did not significantly ($p > .05$) increase the RER at the 2 and 3 mph stages compared with normal walking, but a significant ($p < .01$) increase of 9.7% in RER occurred when arm work was added at the 4 mph stage. As can be seen in Table 4, the use of the CROSS WALK[R]'s arm poles produced significantly ($p < .001$) higher values for all the remaining physiological variables (V_E, kcal, HR, and RPE) compared with normal walking at all three speeds.

Discussion

Although significantly higher MET values (i.e., energy cost) were obtained compared to the ACSM (1991) accepted walking prediction equation for 2 and 3 mph at 3% grade, the differences were within the error of 5 to 8% suggested by the ACSM equation. In contrast, the ACSM (1991) equation underestimated actual VO_2 at 4 mph by over 20%.

The underestimated exercise cost at 2 and 3 mph found in the present study compared to those predicted from the ACSM (1991) equations duplicated the discrepancies found by Montoye and associates (1985) in their extensive study of over 1000 men. These authors found the ACSM (1991) equation also underpredicted the exercise intensities for walking at 3% or level grade. The larger difference found between actual and expected work intensities for the 4 mph stage can also be partially attributed to the 3% testing treadmill elevation. The remainder of the dissimilarity may be attributed to the curvilinear relationship previous authors have found between work intensity and walking speeds greater than 3.7 mph (Bubb, Martin, & Howley, 1985; Miller & Stamford, 1987). This change from a linear model, the basis for the ACSM equation, to a curvilinear relationship for walking speeds in excess of 3.7 mph has been linked with the increased pumping action of the arms leading to an altered stride length and frequency (Maud et al., 1986).

Incorporation of the CROSS WALK[R]'s arm load with treadmill walking produced significant increases in overall exercise costs. The arm work increased relative and absolute VO_2, and MET levels 50% or more over normal walking (i.e., without the arm loads). These large increases in metabolic cost resulted in enhanced total energy consumption by three to four kcal per minute, a 50 to 63% increase. Heart rate also demonstrated large increases of 18 to 24% with use of the arm work. The large exercise intensity increases of the CROSS WALK[R]'s arm work also increased total V_E by as much as 24.2 L•min^{-1} (52%) at 4 mph.

One useful comparison in determining the effectiveness of the CROSS WALK[R]'s ability to enhance exercise intensity is to compare the normal walking speed increases that would be needed to elicit the same physiological responses found by addition of the resistive arm poles. The 7.7 ml•kg^{-1}•min^{-1} rise in VO_2 from use of the arm poles at 2 mph was larger than the 4.1 ml•kg^{-1}•min^{-1} rise found when speed increased from 2 to 3 mph with normal walking. In other words, an individual walking at 2 mph could increase his exercise cost 32% by increasing the treadmill speed to 3 mph or, with use of the arm poles, nearly double (60%) that increase without altering the speed of treadmill.

Using the ACSM (1991) walking prediction equation as a guide, taking into account the equation's expected underestimation for 3% grade, an increase to 3.8 mph would be necessary to elicit the same VO_2 rise found by addition of the CROSS WALK^R's arm poles to walking at 2 mph and 3% grade. In terms of overall energy cost, incorporation of the arm loads at 2 mph is approximately equivalent to a 1.8 mph increase in walking speed.

When the same comparison was used for 3 and 4 mph, the ACSM (1991) walking equation predicted that speeds necessary to elicit the same VO_2 found from addition of the arm poles at 3 and 4 mph were in excess of the 3.7 mph upper limit for the equation. For this reason the ACSM (1991) prediction equation for running was used to determine the treadmill speeds necessary to duplicate the dual action walking intensities found with the CROSS WALK^R at the test speeds of 3 and 4 mph. A running speed of 3.8 mph was necessary for reaching the VO_2 levels of the 3 mph with arm stage. It is unlikely, however, that such a slow running speed would be of practical application. Therefore, the VO_2 level of 27.2 ml•kg^{-1}•min^{-1} found with arm pole walking at 3 mph on a 3% grade seems to lie somewhere in the transition range between walking and running speeds at 3% grade.

The ACSM (1991) equation predicted that running/jogging at 5.3 mph at 3% grade would elicit the VO_2 level found with walking at 4 mph on a 3% grade while using the arm poles. If exercising on level ground, a running speed of over 6 mph according to the ACSM (1991) running equation would be necessary to elicit this intensity. In order to highlight the practicality of this finding, consider the following example. An individual might now be able to reach a training intensity walking at 4 mph with use of the CROSS WALK[R]'s arm poles that he would have only previously attained with running at over 5 mph. If this intensity is necessary for the individual to reach an aerobic training zone, or if the individual experiences discomfort due to the higher impact nature of running, the benefits of the resistive arm poles are more profound.

The arm poles increased heart rates by 18, 24, and 24% at 2, 3, and 4 mph, respectively. These increases were not as large as the VO_2 increases. Thus, an individual monitoring their exercise intensity through heart rate measurement might underestimate actual exertion level while using the resistive arm poles. In addition, heart rates produced at 2 mph with treatment of the CROSS WALK[R]'s arm poles were significantly larger than that of the 3 mph normal walking stage. The same significance ($p < .001$) was found between the 3 mph with arm pole stage and the 4 mph normal walking stage.

In addition, the large increases displayed by VO_2 and HR were not accompanied by similar rises in RPE. The 2 mph test speed with arm poles produced an 18% increase in HR while only a 10% increase in RPE. This difference nearly doubled at the other two test speeds. While arm work at 2 mph produced a VO_2 21% higher than normal walking at 3 mph, the subjects' RPE values were 17% lower at the 2 mph, with-arm stage. This indicates that by assigning part of the work intensity to the upper body through the CROSS WALK[R]'s arm poles, a larger overall metabolic cost can be maintained than would

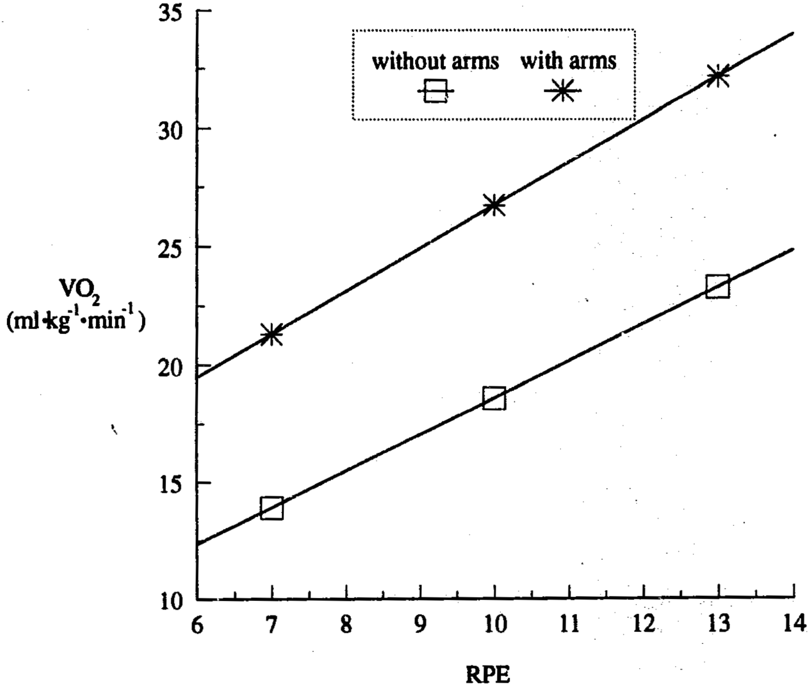

Figure 1. RPE versus VO_2 regression lines for normal walking and walking while using the CROSS WALK[R]'s resistive arm poles at 3% grade.

occur in normal walking at the same perceived exertion. Figure 1 depicts the effect of arm pole usage on the interaction of RPE and VO_2. The equations for the two walking regression lines are:

With arms: VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) = 8.62 + 1.81 x RPE

Without arms: VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) = 2.98 + 1.56 x RPE

The elevation of the with-arm line visually shows the higher VO_2 levels produced by incorporation of the CROSS WALK^{R}'s arm work over normal walking at the same RPE. For example, if an individual were monitoring his or her exercise intensity using perceived cardiovascular strain as a guide, by maintaining an RPE of 10 during normal walking this individual would be exercising at a VO_2 of 18.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (see Figure 1). If this individual were using the arm poles and still maintaining the same RPE, his or her actual VO_2 would be 44% higher (26.7 $ml \cdot kg^{-1} \cdot min^{-1}$).

These findings duplicate results from Gutin and colleagues' (1988) study on combined arm and leg ergometry, suggesting that a lager metabolic load could be performed with little or no increase in RPE. Stenberg et al. (1967) also found that combined leg and arm work was more tolerated than leg work alone at a given intensity level.

The incorporation of arm work affected the overall work intensity differently at each of the test speeds. The metabolic cost indicators (i.e., VO_2, METs, and kcal) yielded large percentage increases in values at 2 and 3 mph when the arm treatment was applied. The augmentation at 3 mph was 1 to 2% larger than at 2 mph. At 4 mph metabolic cost still increased, however, the arm poles effect was approximately 13% less than experienced at the slower speeds. This is consistent with the with results of Auble et al. (1987) who investigated hand weights effect on walking. As speed increased with normal treadmill walking, Auble et al. (1987) found that both arm swing rate and pumping increased. Thus, the arms pump more to maintain faster and faster speeds, and the frequency of the arm swing rises to keep pace with the leg cadence in order to preserve natural walking motion. These result in the recruitment of a larger muscle mass as well as increased demand from the involved musculature in normal walking. This increased involvement of the arms in normal walking situations diminishes the effect of any hand weight or arm pole treatment, resulting in lower increases in VO_2 from any such treatment as walking speeds rise.

Although not assessed in the present study, walking cadence and length of the arm stroke might have attributed to this decrease in percentage gain from involvement of the upper body in another fashion. It is likely that arm stroke length was shortened by the need to maintain pace with the legs. This might be found to have reduced the proportion of overall intensity contributed by the arms. In addition, in order to compensate for the development of overall fatigue as exercise intensity became more difficult, subjects may have decreased the amount of work performed (i.e., length of arm pull) by the arm portion of the total exercise cost since the constant treadmill velocity made reduction of leg work virtually impossible.

Summary

The CROSS WALK[R] generated large increases in VO_2 over normal walking at all speeds. Heart rate, ventilation volumes, kcals, and RPE also increased significantly when normal walking was treated with the upper body loads.

The increases in exercise intensity from application of arm work were not accompanied by similar increases in RPE. For example, walking at 3 mph with use of the arm poles was more intensive than normal walking at the 4 mph condition. The RPE values at 3 mph, however, were lower.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

In order to summarize and draw conclusions from the results of this study, this chapter will view the application of the CROSS WALK^{R}'s unique mode of exercise to the real world. First, comparisons and contrasts of the CROSS WALK^{R} to the other widely used methods of increasing the intensity of walking will be drawn. Second, the potential benefits and problems associated with application of the CROSS WALK^{R} to various populations will be addressed. Finally, suggestions for future research needed to investigate potential problems, explore the feasibility of long term CROSS WALK^{R} use, and ensure safe prescription of the CROSS WALK^{R}'s unique dual action exercise.

Summary

Twenty-nine men were recruited to study the effect of the CROSS WALK^{R}'s resistive arm poles on treadmill walking. Each subject walked for 5 minutes with arm poles and 5 minutes without arm poles at 2, 3, and 4 mph on a 3% grade. The arm poles increased VO_2 (ml•min^{-1}) by an average 58% and HR by an average of 32% above normal walking. The arm poles were found to increase RPE to a much lesser degree averaging a 9.1% increase. Except for RER, the arm pole treatment produced significantly higher levels for all remaining metabolic variables (V_E, L•min^{-1}, kcals, and METs) at all test speeds.

Comparison of Results to Previous Studies

The studies on the effects of hand, wrist, and ankle weights have demonstrated mixed results in increasing the exercise cost of walking. From the literature, only studies employing vigorous arm swings with hand weights were able to generate significant increases in VO_2 (Auble et al., 1987; Maud et al., 1986; Miller & Stamford, 1987; Zarandona et al., 1986).

A comparable increase in exercise intensity produced using the CROSS WALK[R]'s arm poles was found in only one of the hand weight studies (Auble et al., 1987). Auble and associates (1987) produced enhancements as large as 155% over normal walking VO_2 levels. The extremely exaggerated arm movements (pumping the hand weights considerably above the head) used in their study accounts for the large enhancements in work intensity. The remainder of the studies failed to demonstrate walking intensity increases comparable to the CROSS WALK[R].

It is unknown how the CROSS WALK[R]'s upper body exercise compares with the problems associated with hand weights. It may be possible, since the arm poles on the CROSS WALK[R] need only to be griped when pulling toward the user, the elevated diastolic blood pressure associated with hand weight use found by Graves and associates (1987) may be reduced or eliminated. The problem of excessive stress being placed on the arm and shoulder with hand weights, as discussed by previous authors (Auble et al., 1987; Owens et al., 1989), may or may not occur during use of the CROSS WALK[R]. Further investigation is needed to explore these two areas.

Longitudinal exercise studies are one area of research neglected at this time regarding use of weighted walking. It is currently unknown if the vigorous arm swings can be maintained for a 15- to 60-minute exercise session or if this type of exercise bout can be maintained over a training program of months or years. In addition, the problems of injury to the shoulder or small musculature of the arm might occur in acute or chronic application of weighted walking. As the CROSS WALK^R is similar in many ways to the use of hand weights, these same problem areas need to be explored before prescription of the CROSS WALK^R can be safely applied to workout regimens.

Implications of Results

The immediate ability of the CROSS WALK^R to increase exercise cost is evident. Exercise intensity levels for walking at nearly 4 mph can be obtained on the CROSS WALK^R at 2 mph when the arm poles supplement normal treadmill walking. In what ways can this augmentation of work intensity be used in the real world? What populations might particularly benefit from the CROSS WALK^R?

Several groups of individuals are classic examples of people who have trouble maintaining faster walking speed. Persons with orthopedic problems such as foot or knee problems have difficulty or are altogether unable to run due to its high impact nature. Individuals with claudication find that higher speeds bring about their leg pain more quickly. For these groups, the CROSS WALK^R offers the advantage of utilizing slower walking speed for training. This would allow the individuals to reduce current walking speeds and still maintain similar intensities.

On a more broad population level, people who find their natural or comfortable walking speed is unable to elicit an aerobic training heart rate would have an increased chance of maintaining training intensities with use of the CROSS WALK^{R}'s arm poles. This would be increasingly beneficial as individual's aerobic capacity increases with training over time, requiring faster and faster walking speed to reach their target heart rate zone. Thus, by using the CROSS WALK^{R} with its upper body loads an individual might be able to continue using walking treadmill speeds for training instead of having to increase speeds to a running level in order to maintain aerobic exercise intensities.

The CROSS WALK^{R} provides an alternative exercise modality to any exercise regimen which could potentially prevent boredom and increase adherence to an aerobic training program. The lower ratings of perceived exertion for arm pole use compared to comparable normal walking intensities found in this study indicate that individuals might voluntarily maintain higher training levels. Thus, the benefits for overall cardiovascular improvements might occur more swiftly and persons might attain higher levels of aerobic fitness than with walking alone, even though the individual perceives an overall lower work intensity. This would be consistent with the "extremely high maximal aerobic power of cross-country skiers" (Auble et al., 1987, p. 133).

Although not addressed directly in this study, an increase in upper body strength and conditioning might also occur from use of the arm poles. Since strength training and conditioning are recommended by the ACSM (1991), this provides additional benefits to users of the CROSS WALK^R. Increased upper body strength and condition would help those who use their arms in everyday work as well as the elderly in tasks of daily living.

Recommendations for Future Study

This study represents the first research conducted on the newly developed CROSS WALK^R exercise treadmill. Thus, there are many areas that need to be investigated to better understand the benefits of the CROSS WALK^R in real world situations.

Although increases in VO_2 were seen during the 5-minute exercise stages, it is unknown what the effect of the arm work will be over a longer time period. Information needs to be gathered on the ability of subjects to perform the arm work for an entire exercise session. The unfamiliar arm exercise might cause fatigue of arm, chest, or back muscle groups. The same problems might result over a period of days, weeks, or months.

The increases found in this study of over 48% in VO_2 might also decrease with training. This could potentially result from improved conditioning of the upper body, familiarization to the arm pole work, and increased efficiency.

It may also be observed with training on the CROSS WALK^R that individuals might be able to better estimate their actual exercise intensity than was shown in this study. Thus, the perceived lower cardiac strain would diminish which could lead to more appropriate choice of exercise intensity in relation to normal walking.

The problems of a pressor response found with studies on hand weight use might also apply to the CROSS WALK^R's arm poles. Although the poles are not "carried" like hand weights, it might be found that the user's grip (in order to move the CROSS

WALK^{R}'s poles) might artificially elevate blood pressure. If this is found to be true, the CROSS WALK^{R} might not be an exercise modality of choice for hypertensive or coronary heart diseased patients.

Studies to assess the increases in upper body strength and condition need to be conducted. This research should assess which muscle groups are involved in the arm exercise as well as what strength increases an individual should expect to experience through training on the CROSS WALK^{R}.

Conclusion

This research demonstrated the immediate benefits the CROSS WALK^{R}'s upper body exercise poles in enhancing the exercise cost associated with walking. By incorporating the upper body loads, walking speeds can be used to match the work intensities associated with fast walking or even running. Due to the recent introduction of this exercise modality, however, there are many unanswered question. Studies need to be conducted to both assess long term training benefits of the CROSS WALK^{R} and potential problems. Such research should prove valuable in guiding the general public in using the CROSS WALK^{R} for maximal benefits, enjoyment, as well as safety.

REFERENCES

Abadie, B. (1990). Physiological responses to grade walking with wrist and hand-held weights. Research Quarterly for Exercise and Sport, 61, 93-95.

American College of Sports Medicine (1991). Guidelines for exercise testing and prescription (4th ed.). Philadelphia, PA: Lea & Febiger.

Auble, T., Schwartz, L., & Robertson, R. (1987). Aerobic requirements for moving handweights through various ranges of motion while walking. Physician and Sportsmedicine, 15(6), 133-140.

Babyak, D., VanHeest, J., & Rodgers, C. (1991). The effects of Exerstrider use during steady-state treadmill walking on cardiorespiratory parameters. Medicine and Science in Sports and Exercise, 23(4), (Supple 861).

Bobbert, A. (1959). Energy expenditure in level and grade walking. Journal of Applied Physiology, 15(6), 1015-1021.

Borg, G. (1962). Physical performance and perceived exertion. Lund, Sweden: Gleerup.

Bubb, W., Martin, A., & Howley, E, (1985) Predicting oxygen uptake during level walking at speeds of 80-130 m/min. Journal of Cardiopulmonary Rehabilitation, 5, 462-465.

Carroll, J., Pollock, M., Graves, J., Leggett, S., Spitler, D., & Lowenthal, D. (1992). Incidence of injury during moderate- and high-intensity walking training in the elderly. Journal of Gerontology: Medical Sciences, 47(3), M61-M66.

Clausen, J., Trap-Jensen, J., & Lassen, N. (1970). The effects of training on the heart rate during arm and leg exercise. Scandinavian Journal of Laboratory Investigation, 26, 295-301.

Dill, D. (1965). Oxygen used in horizontal and grade walking and running on the treadmill. Journal of Applied Physiology, 20, 19-22.

Fardy, P., Yanowitz, F., & Wilson, P. (1988). Cardiac rehabilitation, adult fitness, and exercise testing (2nd ed.). Philadelphia, PA: Lea & Febiger.

Francis, K., & Hoobler, T. (1986). Changes in oxygen consumption associated with treadmill walking and running with light hand-carried weights. Ergonomics, 29, 999-1004.

Franklin, B. (1989). Aerobic exercise training programs for the upper body. Medicine and Science in Sports and Exercise, 21(5), S141-S148.

Franklin, B., Vander, L., Wrisley, D., & Rubenfire, M. (1983). Aerobic requirements of arm ergometry: Implications for exercise testing and training. The Physician and Sportsmedicine, 11(10), 81-90.

Graves, J., Pollock, M., Montain, S., Jackson, A., & O'Keefe, J. (1987). The effect of hand-held weights on the physiological responses to walking exercise. Medicine and Science in Sports and Exercise, 19, 260-265.

Graves, J., Sagiv, M., Pollock, M., & Miltenberger, L. (1988). Effect of hand-held weights on the metabolic and hemodynamic responses to submaximal exercise in hypertensive responders. Journal of Cardiopulmonary Rehabilitation, 8, 134-140.

Gutin, B., Ang, K., & Torrley, K. (1988). Cardiorespiratory and subjective responses to incremental and constant load ergometry with arms and legs. Archives of Physical Medicine and Rehabilitation, 69, 510-513.

Lewis, S., Thompson, P., & Areskog, N. (1980). Transfer effects of endurance training to exercise with untrained limbs. European Journal of Applied Physiology, 44, 25-34.

Maud, P., Stokes, G., & Stokes, L. (1986). Response to treadmill walking at constant speed: Normal and vigorous arm swing, with and without heavy hand weights. Medicine and Science in Sports and Exercise, 18, S98.

Miller, J., & Stamford, B. (1987). Intensity and energy cost of weighted walking vs. running for men and women. Journal of Applied Physiology, 62(4), 1497-1501.

Montoye, H., Ayen, T., Nagle, F., & Howley, E. (1985). The oxygen requirement for horizontal and grade walking on a motor-driven treadmill. Medicine and Science in Sports and Exercise, 17(6), 640-645.

Mostardi, R., Gandee, R., & Norris, W. (1981). Exercise training using arms and legs versus legs alone. Archives of Physical Medicine and Rehabilitation, 62, 332-336.

Owens, S., Al-Ahmed, A., & Moffatt, R. (1989). Physiological effects of walking and running with hand-held weights. The Journal of Sports Medicine and Physical Fitness, 29, 384-387.

Pollock, M., Carroll, J., & Graves, J. (1991). Injuries and adherence to walk/jog and resistance training in the elderly. Medicine and Science in Sports and Exercise, 23, 1194-1200.

Porcari, J., McCarron, R., Kline, G., Freedson, P., Ward, A., Ross, J., & Rippe, J. (1987). Is fast walking an adequate aerobic training stimulus for 30-to-60 year-old men and women? Physician and Sportsmedicine, 15, 119-129.

Smith, J., Borysyk, L., Dressendorfer, T., Gordon, S., & Timmis, G. (1984). Oxygen requirements during submaximal graded treadmill exercise in coronary heart disease patients: Effect of β-blockade (abstract). Medicine and Science in Sports and Exercise, 16, 189-190.

Stamford, B., Cuddihee, R., Moffatt, R., & Rowland, R. (1978). Task specific changes in maximal oxygen uptake resulting from arm versus leg training. Ergonomics, 21, 1-19.

Stenberg, J., Astrand, P., Ekblom, B., Royce, J., & Saltin, B. (1967). Hemodynamic response to work with different muscle groups, sitting and supine. Journal of Applied Physiology, 22, 61-70.

Thomas, T., Feiock, C., & Araujo, J. (1989). Metabolic responses associated with four modes of prolonged exercise. Journal of Sports Medicine and Physical Fitness, 29, 77-82.

Thompson, P., Cullinane, B., Lazarus, B., & Carleton, R. (1981). Effect of exercise training on the untrained limb exercise performance in men with angina pectoris. American Journal of Cardiology, 12, 844-850.

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

Zarandona, J., Nelson, A., Conlee, R., & Fisher, A. (1986). Physiological responses to hand-carried weights. Physician and Sports Medicine, 14, 113-120.

APPENDIX A

CROSS WALK[R] STUDY INFORMED CONSENT

CROSS WALK^R INFORMED CONSENT

I, ___________________________, volunteer to participate in a study comparing the energy cost of walking on a CROSS WALK^R Dual Motion Cross Treadmill at 2mph, 3mph, and 4mph, with and without using my arms. Prior to the actual test, at least one practice session will be required on the CROSS WALK^R to become familiar with the exercise and the data collection procedures. The actual testing session will consist of walking for five minutes at speeds of 2, 3, and 4 mph with and without hands (testing sequence will be randomly assigned). The time for the total test will be 30 minutes.

During this test I will be breathing room air through a mouthpiece so that my exhaled air can be collected for analysis. Throughout the test my heart rate will also be monitored continuously via an electrode strap fitted around my chest.

As with any exercise this test involves some risks. I may experience dizziness or unsteadiness while walking on the CROSS WALK^R. Wearing the breathing apparatus may cause throat irritation and dryness of the mouth. The arm exercises may produce muscular soreness due to the added resistance of the upper body handles. In addition, I may feel tired at the end of the test. Any unusual or uncomfortable signs and symptoms should be reported to the researchers immediately. In the event of any abnormal physiological responses, the test will be immediately terminated.

My individual information obtained during the laboratory testing will be kept confidential, however, I will be informed of my specific results as well as the group's means and standard deviations.

I consider myself to be in good health and to my knowledge I am not infected with a contagious disease or have any limiting physical condition or disability, especially with respect to my heart, that would preclude my participation in the exercise tests described above. I have read the foregoing and I understand what is expected of me. I accept the risks associated with the testing procedures as described above with no liability against the researchers, Dr. N.K. Butts, Kelly Knox, and T. Shane Foley, the University of Wisconsin-La Crosse, or any staff involved. Any questions which have risen prior to or during the reading and discussion of this consent form have been answered to my satisfaction. I, therefore, voluntarily consent to be tested. Furthermore I know I may withdraw from these tests at any time.

Signed: ____ Date:__________

Witness: _______________________________________ Date:__________