

ABSTRACT

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(J. Porcari)

Power Poles™ are specially constructed, rubber-tipped ski poles designed for use during walking. The user simulates the arm motion of cross-country skiing while walking, thus increasing the muscle mass used during exercise. This study investigated the potential increases in exercise intensity and energy cost associated with the use of the walking poles. Thirty-two healthy subjects (M = 16: age = 23.3 yrs, ht = 69.8 in, wt = 172.1 lb, VO₂max = 58.9 ml/kg/min; F = 16: age = 23.9 yrs, ht = 66.1 in, wt = 140.3 lbs, VO₂max = 49.5 ml/kg/min) completed a treadmill VO₂max test and two randomly assigned, submaximal walking trials (no poles, with poles) on separate days. Each submaximal walking trial was conducted on a level treadmill, for 20 min, at the same self-selected pace (M: x = 4.27 mph; range = 3.98 - 4.80; F: x = 3.77 mph, range = 3.00 - 4.48). VO₂ (ml/kg/min), HR (bpm), and RPE were recorded each min. Results were compared with paired t-tests:

	VO ₂	HR	% HRmax	RPE	Kcal/min
No Poles	19.6	114	59	11.4	6.9
With Poles	24.0*	132*	69*	12.0*	8.4*

*significantly different than no poles (p < .05)

There were no differences in the responses between males and females, thus data were collapsed across gender. It was found that the use of Power Poles™ significantly (p < .05) increased VO₂, HR, and Kcal/min by approximately 20% compared to walking without poles. There were significant (p > .05) differences in calculated oxygen pulse values (mlO₂/beat) between conditions, indicating that the changes were apparently due to the increased muscle mass involved in the exercise and not due to a pressor response mechanism. It is concluded that the use of Power Poles™ can increase the intensity of walking at a given speed, and thus may provide additional training benefits to walkers.

THE PHYSIOLOGICAL RESPONSES TO WALKING WITH AND WITHOUT
POWER POLES™ ON TREADMILL EXERCISE

A MANUSCRIPT STYLE THESIS PRESENTED
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We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

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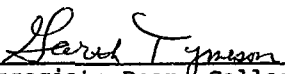

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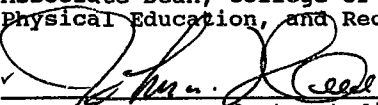

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THE PHYSIOLOGICAL RESPONSES TO WALKING WITH AND WITHOUT POWER POLES ON TREADMILL EXERCISE

INTRODUCTION

Data supporting the importance of regular aerobic exercise as a form of preventative medicine have increased tremendously in the past few years. Paffenbarger, Hyde, and Wing,¹ in the 1986 College Alumni Study, found that men who regularly expended between 500 and 3500 kilo-calories in physical activity each week showed reductions in myocardial infarction and sudden death when compared with more sedentary individuals. The Centers for Disease Control analysis of 43 previous exercise trials showed a significant decrease in the occurrence of coronary heart disease (CHD) when comparing very active with very inactive groups of people.² Blair, Kohl, Paffenbarger, Clark, Cooper, and Gibbons,³ found low levels of physical fitness to be an important risk factor for all-cause mortality in both men and women. Blair et al. also reported that lower mortality rates were seen for cardiovascular disease and cancer of combined sites in higher fitness categories. Even a low-intensity activity (such as gardening) can result in a significant reduction in the onset of CHD.⁴

According to the American College of Sports Medicine (ACSM),⁵ cardiorespiratory fitness activities must incorporate continuous motion and utilize large muscle groups. These activities should be conducted for at least 20 minutes at a heart rate between 60 and 85% of an individual's maximum heart rate. Since there are many types of exercises to choose from, each must be evaluated carefully to determine if it meets ACSM guidelines.

There are many forms of activity that can be prescribed to increase aerobic fitness. Activities such as walking, jogging, cycling, swimming, cross-country skiing, and aerobic dance are all activities that can be performed to achieve a training effect while at the same time maximizing energy expenditure. According to Ward, Malloy, and Rippe,⁶ walking, jogging, and cycling are commonly prescribed forms of exercise because of their consistency of energy expenditure, accessibility, and ease of regulation.

Fitness walking is one of the most popular forms of exercise for weight control and improvement of functional aerobic capacity in apparently healthy adults and cardiac patients.⁶ For people who are unable to jog, walking can provide an adequate training stimulus. In 1987, Porcari et al.⁷ reported that 91 and 83% of men and women, respectively, were able to reach an adequate training intensity (ie., 70% of their HRmax) while walking. It should be noted that the speeds necessary to reach these

intensities (mean of 4.8 mph) may not be comfortable or attainable for many individuals, especially the elderly.

In order to increase the intensity level associated with walking, researchers have studied the use of load carriage while walking. Zarandona, Nelson, Conlee, and Fisher,⁸ found that walking with 5-lb hand-weights produced significant increases in heart rate (HR) and oxygen consumption (VO_2) compared to walking with no weight. Graves, Martin, Miltenberger, and Pollock,⁹ found an increase of 3.8 ml/kg/min when 3-lb wrist weights were raised to chin height while subjects walked compared to walking with no weight. In this same study, when ankle weights of the same weight were used during walking, energy costs increased by only 2.4 ml/kg/min when compared with the no weight trial. In a recent study by Amos, Porcari, Bauer, and Wilson,¹⁰ ankle weights and wrist weights were found to increase the energy cost of walking by 1.7 and 3.5 ml/kg/min, respectively, above the oxygen costs of walking without weights. In this same study HR increased 4 beats/min with ankle weights and 13 beats/min with wrist weights. These results indicate that the energy cost and HR attained from walking can be increased by the addition of ankle or wrists weights, with greater increases being found with wrist weights.

A relatively new product on the market which is proposed to increase exercise intensity while walking are

walking poles. The concept behind the use of walking poles is to incorporate the muscle mass of the upper body while exercising, thus increasing the energy cost of the activity. This would allow individuals to obtain greater benefits from their exercise program.

Walking with poles is very similar to the technique used during the push-off phase in cross-country skiing while diagonal striding. As one leg pushes off from the ground, the opposite arm swings backwards and the pole in this hand pushes off the ground in a position that is parallel to the heel of the push-off foot.

Few studies have been done on the physiological effects associated with hand held pole walking. Further investigation is needed to determine if the use of walking poles can increase the aerobic demand associated with walking.

The purpose of this study was to determine the differences in HR, VO_2 , ratings of perceived exertion (RPE), caloric expenditure (Kcal/hr), and attained exercise intensity of walking with and without POWER POLES™ at a self-selected walking pace.

MATERIALS AND METHODS

Subjects

Thirty-two volunteers (16 male and 16 female) were recruited from the University of Wisconsin-La Crosse and the surrounding community. All subjects completed an informed

consent form approved by the Human Subjects Committee of the Physical Education Department at the University of Wisconsin-La Crosse prior to beginning the study (see Appendix B).

Procedures

Each subject completed two testing sessions held on separate days (no longer than 4 weeks apart). Prior to each testing session, subjects were instructed not to eat, drink, or smoke for at least 3 hours before testing.

On the first day the subject's height, weight, percent body fat, and maximal oxygen consumption (VO_{2max}) were determined. Body density was determined by a series of anthropometric measurements. The equation of Siri (1956) was used to convert body density to percent body fat.¹¹ For females, the equation by Wilmore and Behnke (1970) was used to predict body density.¹² This equation incorporated skinfold measurements of the tricep, subscapula, and thigh. An equation also developed by Wilmore and Behnke (1969) was used to calculate body density for males.¹³ This equation incorporated skinfold measurements at the umbilicus and thigh. All skinfold measurements were made using Harpenden calipers. The average of three measurements at each site was used in the equation to calculate body density.

Subject's VO_{2max} and maximal heart rate (HRmax) were then measured on a motorized treadmill using a modified Balke protocol. Prior to the actual VO_{2max} test each

subject was allowed to practice running on the treadmill to become familiar with the testing procedures and to identify a self-selected speed at which to perform the test. The VO_2max test began with a 4 to 5 minute warmup, walking at a speed of 3 mph and a 10% grade. Following the warm-up each subject began the test, running at their self-selected speed and starting at a 0% grade. The speed of the treadmill stayed constant and the grade progressively increased by 2.5% every 2 minutes until the subject reached volitional exhaustion. Maximal oxygen consumption was determined as the highest 1 minute value of VO_2 attained during the test. The highest HR reached during the test was used as the HRmax .

On the second day of testing each subject completed two submaximal walking trials. One trial was performed with POWER POLES™ (WP) and the second without poles (NP). Since there were 32 subjects tested, 16 completed the WP condition first, followed by the NP condition. The remaining 16 subjects were tested in the reverse order. Before beginning the testing procedures each subject practiced walking on the treadmill to find a comfortable self-selected pace at which to conduct the trials. The average speed for males was 4.3 mph, with a range of 4.0 to 5.0 mph. Females walked at an average speed of 3.8 mph with a range of 3.0 to 4.5 mph.

Subjects were also coached on the proper technique of pole walking. The instructor first demonstrated the

technique of pole walking. Each subject was then instructed to adjust the pole height until the handles of the poles were at elbow level. From the starting position the upper arm should be parallel to the body and the elbows bent at a 90 degree angle. As walking begins the hands should alternately swing forward to chest level (keeping a 90 degree bend at the elbow) and then backward until the arm is almost completely straightened and parallel to the body. All subjects were instructed to use the poles vigorously during the push-off phase of the walking cycle.

Each trial consisted of 20 minutes of walking. Between trials, subjects were allowed to rest until their HR returned to within 10 beats of their resting rate. During both 20 minute walking periods the speed remained identical and the grade of the treadmill was held constant at 0%.

Data Collection

Expired gas volumes and concentrations were analyzed continually during the $\text{VO}_{2\text{max}}$ test and the two submaximal trials using a Quinton Q-Plex metabolic cart (Quinton Instruments, Seattle, WA.). The following variables were determined from the expired gas data: VO_2 , carbon dioxide consumption (VCO_2), and respiratory exchange ratio (RER). These data were averaged and recorded every minute. Total caloric expenditure (Kcal/min) and oxygen pulse (mlO_2/beat) were calculated from these data. Heart rate was also recorded every minute. Ratings of perceived exertion (RPE)

were assessed using the 15 point Borg scale (1983) and recorded at the end of each stage during the VO_2max test and at the end of every minute during the submaximal walking trials.¹⁴

Equipment

Heart rates during all testing procedures were monitored with a Polar Vantage XL model heart rate monitor (Polar Inc., Stamford, CT.). The subjects were required to wear a chest band that contains a transmitter which is located directly over the heart. This transmitter sends signals to a receiver that was worn on the subjects wrist. This receiver has the ability to record and display the subjects heart rate.

Expired air was analyzed using an automated open-circuit gas system (Q-plex 1, Quinton Instruments, Seattle, WA). Gas analyzers were calibrated before and after each testing session using gasses of known percentage previously determined by the Micro-Scholander method.¹⁵ A 3.002 liter syringe was used to calibrate flow meter volumes.

Commercially available POWER POLES™ by Exerscience (a division of NordicTrack Inc.) were used during the submaximal walking tests. These poles are constructed of a lightweight aluminum and weigh approximately 1-lb each (428 grams). The body of the pole is constructed in such a way that it compresses during initial contact with the ground and then springs back to its normal length through the push-

off phase of the walking stride. Additionally, the body of the poles have been made in such a way so that they can be adjusted to the height of the user. The tip of the pole is made of 100% rubber and is designed to be shock absorbent and slip resistant. The handle of the POWER POLES™ are anatomically designed to fit the hand.

Statistical Analysis

Descriptive statistics were performed to calculate mean age, height, weight, $VO_2\text{max}$, HRmax, and percent body fat. The physiological responses of subjects between the two walking trials were analyzed using a two-way ANOVA (sex, condition) with repeated measures. Alpha was set at .05 to achieve statistical significance.

RESULTS

The physical characteristics of the subjects are summarized in Table 1. Subjects ($N = 32$) were recruited from the University of Wisconsin-La Crosse and ranged in age from 19 to 33 years. The males were significantly ($p < .05$) taller, heavier, more aerobically fit, and had a lower percent body fat than the females.

The physiological responses for the two submaximal walking trials (WP and NP) are presented in Table 2. There were no significant ($p < .05$) differences in the responses between males and females for any of the variables measured. Walking with Power Poles™ elicited a significantly ($p < .05$) higher heart rate response than the NP trial. For all

subjects combined the mean WP heart rate was 16% higher than that of the NP condition.

When calculating exercise intensity as a percentage of HRmax, the WP condition enabled all subjects to reach a higher intensity level. Overall, the subjects were able to reach 69% of HRmax during WP while the NP condition elicited 59% of HRmax.

Table 1. Descriptive characteristics of subjects (N = 32)

	Females (n = 16)	Males (n = 16)	Total Group (N = 32)
Age (yrs)	23.9 ± 3.36	23.3 ± 62.77	23.6 ± 3.05
Height (ins)	66.1 ± 1.71	69.8 ± 2.65*	67.5 ± 2.86
Weight (lbs)	140.3 ± 17.45	172.1 ± 12.73*	156.2 ± 22.07
VO ₂ (ml/kg/min)	49.5 ± 6.65	58.9 ± 6.71*	54.2 ± 8.14
HRmax	189.9 ± 10.13	193.0 ± 8.47	191.4 ± 9.32
%BF	24.9 ± 2.33	14.8 ± 2.53*	19.9 ± 5.66

All values represent mean ± standard deviation.

* Significantly greater than females (p < .05).

Mean VO₂ values for the WP condition were significantly (p < .05) higher than values for the NP condition (see Figure 1). For all subjects combined, the mean VO₂ for the WP trial was 4.4 ml/kg/min higher than the VO₂ attained during the NP trial. The range of percentage increase between the two walking trails was quite large, ranging from a low of 8% to a high of 37%.

Table 2. Physiological responses to walking with and without Power Poles™

	NP	WP
<u>HR (bpm)</u>		
Males	114 ± 11.5	129 ± 13.2*
Females	113 ± 15.6	134 ± 19.2*
Overall	114 ± 13.5	132 ± 16.5*
<u>VO₂ (ml/kg/min)</u>		
Males	21.7 ± 1.81	26.9 ± 2.26*
Females	17.6 ± 2.69	22.1 ± 2.91*
Overall	19.6 ± 3.08	24.0 ± 3.23*
<u>Kcal/hr</u>		
Males	496 ± 58.0	598 ± 70.2*
Females	326 ± 68.0	413 ± 75.0*
Overall	411 ± 106.5	505 ± 118.1*
<u>RPE</u>		
Males	10.6 ± 1.67	11.7 ± 1.94*
Females	10.3 ± 1.46	12.2 ± 2.27*
Overall	10.4 ± 1.55	11.5 ± 2.10*
<u>Oxygen pulse (mlO₂/beat)</u>		
Males	14.9 ± 1.65	16.4 ± 3.02*
Females	10.1 ± 2.57	10.7 ± 2.58*
Overall	12.5 ± 3.27	13.6 ± 4.02*

All values represent means ± standard deviations.

*Significantly different than NP condition (P < .05).

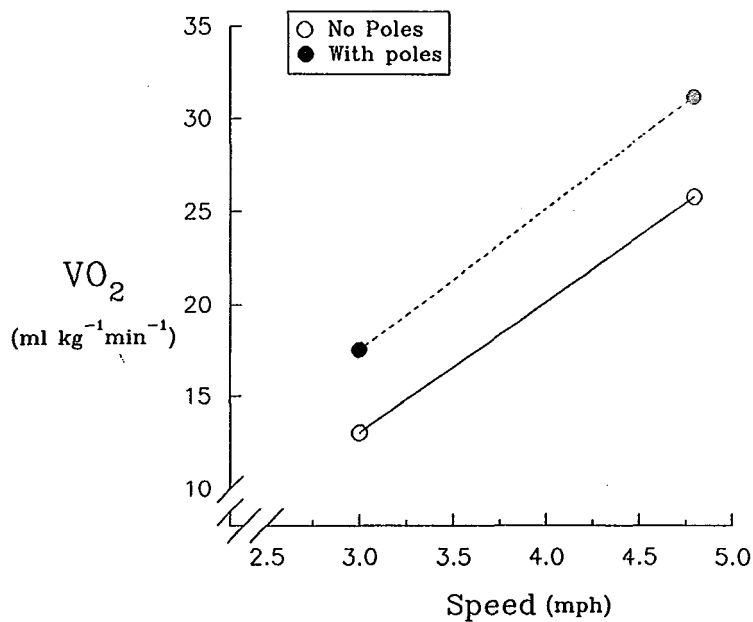


Figure 1. Plot of oxygen consumption versus speed when walking with and without Power Poles TM

During the WP trial the average rate of total energy expenditure was 23% greater than the NP trial. The overall range of percent change for caloric expenditure was also quite large (8 to 40%).

Both males and females showed a significantly ($p < .05$) higher RPE for WP compared to NP. Overall RPE increased 1.1 units on the Borg 15 point scale from the NP to the WP trial.

There were small but significant ($p < .05$) differences in calculated oxygen pulse values (mlO_2/beat) between conditions, indicating that the increase in exercise intensity was most likely caused by the increased upper body muscle mass during the WP trial and not due to a pressor response.

DISCUSSION

These analyses tried to determine if walking with Power PolesTM could increase exercise intensity compared to NP when walking at an identical speed. In the current study, the WP trial was found to significantly increase VO_2 , HR, caloric expenditure, and RPE compared to the NP trial. Also, responses were similar for males and females for all variables. Since research regarding walking poles is limited, the responses seen in the present study will also be compared to those using wrist and hand weights.

The oxygen cost of walking with 1 lb Power PolesTM was found to increase by 4.4 ml/kg/min (23%) compared to the NP

trial. Studies using 1 lb wrist or hand weights have found increases in oxygen cost ranging from .10 to 3.6 ml/kg/min above that of normal walking.^{8,16-19} The results of Auble, Schwartz, and Robertson are most similar to the current study¹⁶. They found the oxygen consumption of walking to increase by 3.6 ml/kg/min (17%) while pumping 1 lb weights through a .61 range of motion, when compared to normal walking. The smaller increases seen in the other studies were probably due to a decreased vertical hand displacement (less than .61 meters) when using hand or wrist weights.

An overall increase in HR of 18 bpm was found during the WP trial compared to the NP trial. Similar studies incorporating the use of hand weights while walking have found increases in HR as well, ranging from 7 to 13 bpm above that of walking without hand weights.^{8-10,17,18} Differences in findings between studies again can be attributed to differences in the amount of weight used and variations in degree of arm swing used to pump the weights.

To this author's knowledge, there have been three previous studies conducted looking at the acute effects of walking with poles. All three studies found similar results to those found in the current study. Babyak, VanHeest, and Rodgers compared the energy cost of walking on a treadmill at 4.2 mph with and without the use of walking poles.²⁰ The energy cost of walking with the poles was approximately 12% (20.5 vs. 18.3 ml/kg/min) higher than walking without the

poles. They also found pole walking to increase HR and caloric expenditure by 9 and 17%, respectively, over the no-pole trial.

In an unpublished masters thesis by Robaidek,²¹ the addition of poles to walking increased the VO_2 response associated with walking by 3.7, 3.5, and 4.9 ml/kg/min at 3.0, 4.0, and 5.0 mph, respectively. Robaidek also found increases in HR during all three speeds to be 10% higher than the heart rates reached during normal walking.

In an unpublished masters thesis by Licata,²² the physiological responses of normal walking were compared to those of walking with the addition of hand weights and walking poles. Licata found VO_2 to increase by 22% and HR to increase from 101 to 113 beats/min when using walking poles. Increases in VO_2 and HR while using hand weights were similar to the increases found while walking with poles.

According to the ACSM (1991) the minimum training intensity threshold for improvement in cardiorespiratory endurance is approximately 60% of HRmax (50% of $\text{VO}_{2\text{max}}$ or HRmax reserve).⁵ In the current study, when expressing exercise intensity as a percentage of HRmax, intensity progressed from 59% during the NP trial to 69% during the WP trial. Thus, the addition of poles during walking was effective in eliciting a greater HR response and bringing individuals to the recommended training zone without having

to run. The ability to increase exercise intensity during an activity should allow an individual to obtain greater physiological benefits from their exercise program. In a 1991 study by Postmus et al.,²³ walking with and without walking poles was found to reduce body fat and increase aerobic performance to a similar magnitude. However, the group of subjects walking with poles was able to obtain these changes while walking .3 mph slower.

When interpreting HR responses it is very important to consider the possibility of a pressor response occurring. The occurrence of a pressor response could not only be dangerous to the exerciser, but also would tend to cause an exercise prescription based on the heart rate method to be inaccurate. In the current study the increased HR during the WP trial was associated with a slightly larger increase in VO_2 , relative to HR, indicating that the addition of the arms made walking a more aerobic form of exercise. Thus, a pressor response did not occur.

In the present study, cumulative energy expenditure was 96 Kcal/hr greater when using WP compared to the NP trial. This represents a 23% increase in energy expenditure. Similar studies by Miller and Stamford,²⁴ and Makalous, Araujo, and Thomas,¹⁸ found significant increases in caloric cost while walking with hand weights compared to walking with no weights. The increase in caloric expenditure due to

the use of the Power PolesTM should allow the exerciser to lose weight more rapidly.

Rating of perceived exertion values were significantly higher with the use of WP over the NP trial. The increases in RPE values corresponded with the increases in VO_2 and therefore may be attributed to the increased energy demands of the WP trial. The magnitude of the increase in RPE was similar to several studies that used hand weights while walking.^{10,17,25} Another possible explanation for the increase in RPE found during the current study could be due to the fact that the subjects were not accustomed to using their arms during exercise to the extent that they were required to during the WP trial. The added weight of the POWER POLESTM, the added increase in range of motion that the arms traveled, and the pole push-off phase all may have contributed to the increased localized fatigue in the upper body.

In previous studies, hand weights have sometimes resulted in an exaggerated SBP response due to the gripping involved in holding the weights.^{17,26} Since blood pressure was not measured in the current study it is impossible to report on the effects that POWER POLESTM had on the blood pressure of the subjects being tested.

During exercise systolic blood pressure (SBP) should rise in a linear fashion as a function of exercise intensity (approximately 10 mm Hg per MET), but diastolic blood

pressure (DBP) should fall moderately or remain unchanged from resting values.⁵ In 1988, Licata measured the effects of walking with hand weights and walking sticks on blood pressure.²² He found SBP to increase with walking intensity, but to a greater extent while using hand weights. When using hand weights SBP increased by 16 mm Hg above the normal walking trial and only 11 mm Hg during the walking pole trial, despite similar increases in VO_2 . Licata found that DBP increased above resting levels during the use of hand weights and walking sticks, but only the use of the hand weights resulted in a significant increase. It should be noted that the design differences that exist between the walking poles and hand weights allows for different usage techniques. When performing exercise with walking poles, the backward movement of the arms can be accomplished without gripping the handle of the pole firmly, thus eliminating any isometric contraction of the forearm. Conversely, hand-held weights must be gripped throughout the entire exercise causing an isometric contraction to occur.

There are many potential benefits that can be associated with the addition of WP to an existing walking program. For example, most occupational and recreational activities require combined upper and lower body work or, at times, possibly upper body work alone. Ideally, a perfect exercise modality would be one in which an individual can cross-train both the upper and lower extremities at the same

time to improve muscular strength and endurance. In a study by Karawan et al.,²⁷ upper body endurance was found to increase by 38% following 12 weeks of pole walking, but upper body strength did not change. It was concluded that walking with poles can substantially increase muscular endurance but may not provide sufficient stimulus to increase muscular strength.

There is an increase in the risk of orthopedic injury when a person proceeds from walking to running.²⁸ If done properly, the addition of WP to an exercise program can increase exercise intensity without an individual having to run. This in itself may make pole walking an attractive alternative for individuals who are unable to run. In addition, the poles themselves may help to absorb some of the shock to the lower body that occurs when the feet strike the ground, thus eliminating much of the stress put on the joints of the lower extremities.

There also exists the potential for injuries to the upper body. When using WP the arms must travel through a relatively large range of motion while carrying a 1 pound pole in each hand. Additionally, the arms must be used to drive the poles back and propel the body forward during the push-off phase of the walking cycle. This repeated demand of the arms may precipitate injuries in the upper body muscles and joints. Even though this is a possibility, the subjects in the 12-week training study by Karawan et al.²⁷

reported no upper body injuries as a result of training with poles.

Finally, the use of walking poles have been shown to result in a hypertensive response in some individuals. This could be contraindicated in certain individuals especially those with cardiovascular disease. Thus, WP should be prescribed using precautions similar to those used when implementing any new exercise program, particularly among those individuals in which a hypertensive response is contraindicated. If the potential for a hypertensive response is questionable, the individual should be tested in a laboratory setting with appropriate ECG and BP monitoring prior to prescribing an exercise program using WP.

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APPENDIX A
REVIEW OF LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

This review of literature relates to the effects of walking with and without Power Poles™ on treadmill exercise. Out of necessity this literature review will focus on studies evaluating the physiological response to walking with hand and wrist weights because these exercise modalities most closely resemble the exercise modality examined in this study. This review covers the following areas: the importance of walking as a form of exercise, walking vs. running, weight-loaded walking, the negative effects associated with walking with hand weights, and finally similar modes of exercise related to walking with poles.

The Importance of Walking

In an article entitled "Walking for Health and Fitness" (Rippe, Ward, Porcari, & Freedson, 1988), a panel of four researchers commented that even low and moderate intensity exercise such as walking, when carried out consistently, is associated with important cardiovascular health benefits. They state that walking may help reduce anxiety, tension, aid in weight loss, improve cholesterol profiles, help control hypertension, and slow the process of osteoporosis. Walking is a form of exercise that can be accomplished by

almost anyone. Different than many other forms of exercise, walking can be accomplished in almost any environment without the need for special equipment or skill. Stamford (1986) stated that the biggest advantage to walking was the ease with which it could be performed in any place at any time.

According to Schultz (1980), walking is the most commonly prescribed exercise for cardiac rehabilitation patients. Schultz also states that walking enables these individuals to improve aerobic conditioning, relieve stress, and lose weight without an increased risk of musculoskeletal problems.

Decreases Coronary Heart Disease

Many important epidemiological studies have linked consistent physical activity with decreased risk of developing coronary heart disease (CHD) (Leon, Connett, Jacobs, & Rauramaa, 1987; Paffenbarger, Hyde, & Wing, 1986). Leon et al., (1987) concluded that men at high risk for CHD who self-selected moderate amounts of predominately light and moderate nonwork physical activity had lower rates of CHD mortality, sudden death, and overall mortality than sedentary men.

Other studies have compared the incidence of CHD in active versus sedentary lifestyles. The Coronary Drug Project (1973) was one study that looked at physical activity and mortality. Findings of the study show that

individuals who engaged in moderate to vigorous modes of activity had a lower mortality rate and fewer sudden deaths than those individuals who engaged in light activity. In a 1986 study by Rippe et al., sedentary individuals were shown to have an increased rate of mortality and CHD over that of active individuals. They also stated that active individuals have a lower incidence of obesity, osteoporosis, and hypertension.

Cardiovascular Benefits

A number of studies have been done on the cardiovascular benefits associated with walking. Most have concluded that fast walking is an adequate stimulus to cause increases in cardiorespiratory fitness and decrease body fat (Pollock et al., 1971; Porcari et al., 1987; Rippe et al., 1986; Schultz, 1980).

In a study conducted by Pollock et al. (1971) the effects of walking on cardiovascular function and body composition were tested. Sixteen untrained males volunteered for 20 weeks to train 4 times each week for 40 minutes per workout. It was found that maximal oxygen uptake increased by 28% and DBP was reduced significantly (2.8 mm Hg). Analysis of body composition showed that total body weight decreased by 1.3 kg and percent body fat by 1.1%. It was concluded that vigorous walking does have a significant impact on overall body composition and cardiovascular functioning.

Porcari et al. (1987) conducted a two part investigation to determine if fast walking was an adequate aerobic stimulus for 30 to 69 year old men and women. A training HR was defined as a heart rate greater than or equal to 70% of a person's HRmax. In the first phase of the study, 343 subjects (165 men and 178 women) walked a mile as fast as possible. Ninety-one percent of all the women and 83% of the men 50 years of age and older attained a HR equal to or greater than 70% of maximum. In the second phase, 10 highly trained men were instructed to walk for 30 minutes at a pace that would elicit at least 70% of their HRmax. During the exercise all subjects were given feedback on their HR. For an average of 25 minutes, all individuals were able to maintain a pace that elicited their target heart rate. The results of these two studies seem to show that fast walking can elicit an adequate aerobic training stimulus. The walking speed necessary to achieve these intensities, however, may not be comfortable for many individuals.

Risk of Injury

According to Stamford (1986) there is an increase in the risk of orthopedic injury when a person proceeds from walking to running. He added that the increases in rate of injury associated with running can be attributed to the increased force with which the feet strike the ground.

In an earlier study (1984), Stamford stated that the impact forces of the heel are 3 to 5 times greater for running than walking. The constant pounding effects the ankle, knee, and hip joints, increasing the chances for injury to those areas. He adds that walking is a safe form of exercise for older adults and overweight individuals. Rippe et al. (1986) also commented on the decrease in injury associated with walking as a form of exercise as opposed to many other forms of exercise, such as running or high impact aerobics.

In 1982 Daffner, Martinez and Gehweiler reported that the portion of our population that runs several miles daily experience musculoskeletal injuries, such as muscle strains, ligamentous abnormalities, and stress fractures more often than individuals who chose not to run. In a similar study by Newell and Bramwell (1984), they reported that anywhere from 23 - 40% of the runners in a number of studies had knee complaints. They stated that the reason for this is that there are more runners, running more often and for longer distances.

Weight-Loaded Walking

Each year researchers develop new and exciting ways to exercise. Adding weight to exercise has become a popular topic for research in the past few years. Findlay (1984) states that this is most likely due to the incredible claims manufactures advertise. More often than not manufactures

tend to exaggerate the claims of their product. In 1969 Soule and Goldman reported that the increased energy cost of adding weight while exercising is of greater magnitude when weight is added to the extremities instead of the torso. This is especially true when adding weight to the feet instead of the torso. The subjects studied carried 4 or 7 kg in their hands, or 6 kg on their ankles. The researchers found that when weight was carried on the feet the energy cost increased greatly (6 times that of no weight). In addition, loads carried in the hands cost nearly twice as much relative energy expenditure than loads carried on the torso.

Additional studies have been done comparing the effects of ankle and hand weights on the energy cost of walking that conflict with the findings of Soule and Goldman (1969). According to Miller and Stamford (1987), regardless of the intensity of effort or treadmill speed, when weight is added during walking, the increases were greater for hand weights than ankle weights. Graves, Martin, Miltenberger, and Pollock (1988), performed a study comparing the effects of hand weights, wrist weights, and ankle weights. Energy expenditure and HR response were significantly greater for ankle, wrist, and hand weights when compared to the nonweighted condition. Additionally, energy expenditure and HR response were found to be greater in wrist and hand weights when compared to ankle weights.

Even though exercising with weight added to the feet tends to increase the energy cost associated with nonweighted exercise, this form of exercise has little if any benefit for the upper body. This is why exercising with hand weights has become increasingly popular in the past few years. Proposed benefits of hand weight exercise include increases in energy expenditure, exercise intensity, and potential for strengthening the muscle groups involved in the activity (Stamford, 1984).

Franklin (1985) suggests that the increased energy expenditure caused by swinging hand weights during walking can produce metabolic loads comparable to slow jogging while also providing an upper extremity workout. The popularity of this form of exercise has peaked the interest of researchers to report on the physiological responses associated with it. Of the studies reviewed many show inconsistencies with one another. In order to evaluate the differences of each study it is necessary to evaluate each of them individually.

Exercise with Hand Weights

In a 1987 study by Auble, Schwartz, and Robertson, nine male subjects walked with and without hand weights at speeds of 1.12 to 1.79 m/sec. This study compared the metabolic requirements of normal walking (without hand weights and with normal arm motion) with requirements of walking while pumping 1, 2, or 3 lb hand weights through various ranges of

motion. In this study adding weight to the arms produced significant increases in oxygen consumption. As the range of arm movement increased so did energy expenditure. When the pumping height was lowered to the shoulders, gains in VO_2 were not as significant. The VO_2 for hand weighted walking ranged from 17 to 43 ml/kg/min, or 113 to 255% of normal walking requirements at any given speed. In this study the subjects were instructed to pump the hand weights as they walk in a rhythmic motion, the arm movements were more vigorous than those used during ordinary walking. The intensity of these movements may explain the large increases in energy expenditure that were documented in this study. Auble et al. (1987) concluded that the addition of hand weights to walking provides an aerobic stimulus for and exerciser of any fitness level. Similar studies examining the physiological responses associated with hand weighted walking have found results far smaller in magnitude.

Owens, Al-Ahahmed, and Moffatt (1989), studied the effects of walking and running with hand weights on VO_2 , HR, RER, and RPE. Protocols consisted of carrying one of four randomly assigned weights (0, 0.45, 1.36, and 2.27 kg per hand) while walking or running for 5 minutes on a treadmill at each of four speeds (4.8, 6.4, 8.0, and 9.6 km/hr) at 4% grade. Subjects were instructed to maintain a normal arm swing pattern while exercising. The results of this study suggest that walking with hand weights of 2.27 kg or less

while maintaining a normal arm swing is an insufficient stimulus for significantly increasing VO_2 or HR. It appears that adding hand weight to walking has little if any effect on VO_2 or HR if arm swing patterns are held constant to normal walking.

Francis and Hobbler (1986), determined that walking with hand weights did not significantly increase VO_2 (oxygen uptake increased only 1.0 to 1.5 ml/kg/min). In this study subjects were instructed to only carry the hand weights while walking, no further instruction was given. It is possible that reduced arm movements may have contributed to the lack of significant increases in VO_2 . Francis and Hobbler (1986) concluded that the aerobic benefits of using hand weights while walking did not significantly alter VO_2 . In addition, they state that even though the VO_2 while running with .91 kg and 1.8 kg hand weights was statistically greater than running without weights, the physiological significance of these increases may not be important.

Finally, in a study by Claremont and Hall (1988), the commercial claims of increased energy expenditures (30 to 300%) associated with the use of hand weights during running were examined. This study included a biomechanical analysis of the kinematics of walking with hand weights. They noted that the distance the arms traveled was significantly reduced and suggested that this explained the lack of

significant changes in VO_2 . The results of this study suggest that commercial claims of marked increases in energy expenditure during running with hand weights are exaggerated.

Some of the variance among these studies can be attributed to the varying differences in vertical arm displacement, lack of weight standardization, and variance in walking speeds.

In order to accurately assess the physiological changes associated with the use of hand weights it may be beneficial to evaluate the data from studies that shared a similar experimental design (Graves, Pollock, Montain, Jackson, & O'Keefe, 1987; Graves et al., 1988; Miller & Stamford, 1987; Zarandona, Nelson, Conlee, & Fisher, 1986). In these four studies the vertical displacement of the arms were similar. All four studies required subjects to carry the weights with a 90° bend in the elbow, and to swing the weights in an arc from the umbilicus to the sternoclavicular joint. In addition, the walking speeds and weight carried were similar for all four studies. The speeds at which the subjects walked ranged from 54 m/min to 107.3 m/min, and the weight carried in each hand varied from .45 to 2.25 kg. When comparing the results of these four studies the differences they found in the physiological changes associated with hand weighted walking are minimal.

In a study by Zarandona et al. (1986), 30 trained men carried either 0, .45, or 2.25 kg weights in each hand on a motorized treadmill at a speed of 3.5 mph (93.9 m/min). Results show that both walking and running while carrying 2.25 kg weights produced a significant increases in VO_2 , but only walking produced significant increases in HR. The increase in VO_2 found by Zarandona et al. (1986) averaged 5.0 ml/kg/min. A study by Miller and Stamford (1987) agrees with the findings of Zarandona et al. (1986). This study employed a nearly identical experimental design and found very similar results. This study analyzed the energy cost and intensity of walking at 0% grade at 2, 3, and 4 mph (54, 80.5, and 107 m/min) with 2.25 kg hand weights. At these speeds the increase in VO_2 averaged 6.4 ml/kg/min.

Two separate studies by Graves et al. (1987 & 1988), found similar results to the two studies mentioned above. During both of these investigations Graves et al. investigated the cost of walking with 2.25 kg hand weights at various speeds. In the 1987 study, Graves et al. found VO_2 to increase by 3.3 ml/kg/min. In the 1988 study they found VO_2 to increase by 3.8 ml/kg/min, regardless of speed.

In all four of these investigations (Graves et al., 1987; Graves et al., 1988; Miller & Stamford, 1987; Zarandona et al., 1986) HR increased significantly. Taken together, these findings suggest that the interaction between vertical hand displacement and the amount of weight

being carried have a dramatic effect on the VO_2 and HR responses associated with walking.

Negative Effects of Hand Weights

Unfortunately there are negative effects associated with the use of hand weights when incorporated into a walking program. The two main negative effects associated with the use of hand weights while walking include a hypertensive blood pressure (BP) response and increased chance of injury to the upper extremities.

The use of hand weights poses an increased clinical risk to persons who are hypertensive, have a hypertensive response to exercise, or have a diminished functional reserve (DeBusk, Pitts, Haskell, & Houston, 1979). This response may result from an increased total peripheral resistance caused from the isometric contraction of the forearms during hand weight exercise. According to Jackson, Reeves, Sheffield, and Burdeshaw (1973), when an isometric exercise component is added to a dynamic exercise task, BP is elevated above levels noted for the dynamic exercise alone. The data of Jackson et al. (1973) suggest that the afterload associated with isometric exercise can be additive to the preload produced by dynamic exercise. Thus the addition of the muscles of the upper extremity, and their isometric hand gripping, or both may be responsible for the increases in BP associated with hand weight exercise. Other studies have shown that carrying hand weights while doing

rhythmic leg exercise elicits a pressor reflex in which HR and BP rise disproportionately to VO_2 (Graves et al., 1987). According to Jackson et al. (1973), this reflex may be caused by an isometric contraction of the hand to hold the weight, or by the static forces required to maintain a 90° bend at the elbow. Previous research has shown that the addition of hand weights can exaggerate the BP response to walking exercise in some individuals (Amos, Porcari, Bauer & Wilson, 1992; Graves et al., 1987; Graves et al., 1988; Zarandona et al., 1986).

Increased chance of injury to the upper body extremities is an additional risk associated with the use of hand weights. According to Stamford (1984), swinging weights in large circles with the elbows straight puts a tremendous strain on the shoulder and elbow joints and can injure fragile connective tissue. The risk associated with weighted walking compared with running may be less because there is no airborne phase in walking. However, according to Miller and Stamford (1987) there is an increased risk of elbow tendinitis (tennis elbow) when using hand weights.

The use of hand weights can also be associated with the development of back problems (Rippe et al., 1986). McDonough and Razza-Doherty (1988) state that the vigorous arm movements associated with hand weighted walking places an increased torque on the back. In addition the upper body

rotates in an opposite direction to the lower body to cancel the angular momentum during walking.

Claremont and Hall (1988) evaluated the biomechanical responses associated with walking with hand weights. They concluded that the addition of a load to any portion of the body typically increases the impact forces of every footfall, an effect which may contribute to the likelihood of injuries. Claremont and Hall added, that if the inconvenience and discomfort of carrying hand weights are considered, it would appear that increasing running speed and distance would be a more desirable method in which to increase energy expenditure.

A Similar Mode of Exercise

It makes sense for manufactures to develop equipment which enables the exerciser to use both upper and lower body muscle groups, especially when there is abundant evidence supporting the fact that training is specific to the muscle groups involved (McArdle, Katch, & Katch, 1986).

One popular form of exercise equipment that is similar to walking with hand-held poles and that has become very popular is cross-country ski simulators. One study found that 22 previously sedentary women (age 20 to 40) improved their VO_{2max} values by 12% after training for 19 weeks, 4 times a week for 20 to 40 minutes on a NordicTrack™ cross-country ski simulator (Jacobsen, Leon, & Wang, 1986). According to Jacobsen et al. (1986), this form of exercise

may be as effective as stationary bicycling and rowing in providing aerobic training benefits. It should be emphasized, however, that it is very difficult to measure the metabolic cost of using this form of equipment due to the difficulty in calculating the workload that the machine is providing.

Cross-country skiing is generally considered an excellent form of aerobic exercise. It is one that can be performed during the winter months outdoors and also indoors on ski simulators. Cross-country skiing also enables the exerciser to get a full body workout while performing a low impact form of exercise. The use of Power Poles™ simulates that of cross-country skiing. Thus, one may expect similar results from their use. One advantage that walking with Power Poles™ has over cross-country skiing is that it does not require snow. Power Pole™ walking is a form of exercise that can be performed year round in any type of outdoor environment.

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APPENDIX B
INFORMED CONSENT

INFORMED CONSENT

THE EFFECTS OF WALKING WITH AND WITHOUT POWER POLES™ ON
TREADMILL EXERCISE

I, _____, would like to volunteer to participate in a project to determine if the use of Power Poles™ while walking on a motorized treadmill increases the physiological responses associated with walking. Participation in this project requires that I complete a maximal oxygen consumption test on a treadmill, have my percent body fat calculated by means of skinfold measurements, and perform two walking trials (one with Power Poles™ and the other without).

The maximal oxygen consumption test will consist of running to voluntary exhaustion on a motorized treadmill. The speed of the treadmill will be self-selected and stay constant. The grade of the treadmill will increase 2.5% every 2 minutes throughout the test.

Percent body fat will be calculated by a series of anthropometric measurements. I will be asked to go through a series of measurements that will be taken with skinfold calipers. I understand that the use of hand calipers to measure body fat may cause momentary discomfort.

Walking trials will consist of walking on a motorized treadmill for 20 minutes at a self-selected speed. The speed and percent grade of the treadmill during each trial will stay constant. I may rest between trials to allow my heart rate to drop to within 10 beats of my pre-exercise heart rate.

As with any exercise, there exists the possibility of adverse cardiovascular changes (i.e. dizziness, shortness of breath, heart attack, etc.) during either testing sessions. However, if any abnormal observations are noted at any time, the test will be terminated immediately. In addition, I will probably feel tired or sore at the end of each testing session.

All testing sessions will be scheduled at my convenience. The tests will be conducted by Thomas L. Hendrickson a graduate student enrolled in the Adult Fitness/Cardiac Rehabilitation Graduate Program under the direction of John Porcari, Ph.D. The results of all tests will be thoroughly

explained upon completion of the test and all data will be confidential. I do however give permission for the data to be used for research purposes.

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 regard to my heart, that would preclude my participation in the tests described above. I have read the foregoing and I understand what is expected of me. Any questions which may have occurred to me have been answered to my complete satisfaction. I therefore voluntarily consent to be a subject in this study. Furthermore, I know I may withdraw at any time without any type of penalty.

SIGNATURE OF SUBJECT _____ DATE _____

SIGNATURE OF WITNESS _____ DATE _____