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The Energy Cost of Nordic Walking

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My advisor made some changes to my research paper. Since it will be posted on OPENSIUC, he wanted to make some technical changes to the paper. I have already gotten this paper accepted, and the changes on this paper are minor, but necessary.

THE ENERGY COST OF NORDIC WALKING

by

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A Research Paper

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CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

The additional muscle recruitment associated with upper-body work during walking has been found to significantly increase caloric expenditure at any given walking speed (Church, Earnest, & Morss, 2002). As described by Hansen and Smith (2009), it is an attractive feature of Nordic walking that average rate of oxygen uptake, which reflects energy expenditure and might be thought of as "productivity" during a fitness activity, is reported to be up to 23% higher than during ordinary walking at fixed velocities. Notably, the greater energy expenditure of Nordic walking has been reported without increasing the rate of perceived exertion (RPE) (Hansen & Smith, 2009).

Several studies have been done to measure the energy expenditure of Nordic walking compared to regular walking at fixed velocities. Prior studies have examined the energy expenditure while using the same velocity for Nordic and treadmill walking. RPE has been obtained while performing the walking variations. No prior studies have set the RPE and let participants set the Nordic and regular walking speeds that correspond to that RPE and measured the response.

Nordic walking is believed to provide physiological adaptations that provoke better health amongst those individuals who walk. Willson et al. (2001) reported increased self-selected walking speed with poles compared with walking without poles and decreased stress on knee and ankle joints resulting from the forces during shoe-ground contact. Willson et al. (2001) later concluded that reduced average ground reaction forces during foot ground contact during Nordic walking compared with normal walking lead to less lower extremity loading. Decreased loading of the leg extremities while walking reduces stress on the legs, but also dissipates the perceived exertion by involving the upper body. Reduced lower leg loading provides important benefits for older populations who cannot withstand continued stress to their lower extremities. By using poles to engage the upper body and redistribute weight-bearing to the lower extremities, one can reduce stress on the knees and hips, improve posture and endurance, and reduce the risk of falling (Nordic Walking Older Adults, 2009).

Research Hypothesis

The purpose of the present study was to compare the oxygen uptake and heart rate responses of Nordic and treadmill walking at the same rating of perceived exertion. The following two observations were hypothesized: (a) while walking at a speed that elicits the same RPE, Nordic walking participants would have a greater oxygen uptake than regular walking, (b) the heart rate will be higher while Nordic walking despite having the same RPE as regular walking.

Limitations

Because some factors are beyond the control of the researcher, the following limitations were placed on the study.

1. The results may not be transferrable to practical Nordic walking since participants Nordic walked on a treadmill during this study.

2. Restrictions were not placed on diet or physical activity prior to engaging in the testing. These factors may affect the results of the test.

3. Subjects may use different Nordic walking techniques that may increase or decrease exertion.

Operational Definitions

Borg RPE Scale. Subjective measure of how hard a person feels they are working physically. The ordinal scale is measured from 6, "no exertion at all", to 20, "maximal exertion".

Energy expenditure. The amount of energy that a person uses to breathe, circulate blood, digest food, and be physically active.

Maximal oxygen uptake (VO_2max). The maximum capacity of an individual's body to transport and utilize oxygen during incremental exercise which reflects the physical fitness of the individual. Expressed as absolute value in $L \cdot min^{-1}$ or relative value in $ml \cdot kg \cdot min^{-1}$.

Minute ventilation (VE). Volume of air exhaled from a person's lungs in one minute.

Nordic walking. Physical activity that involves walking with poles which includes upper and lower body musculature.

Walking/jogging warm-up. A submaximal physical exertion that induces blood flow to the periphery.

CHAPTER 2

REVIEW OF LITERATURE

Only three prior studies have been done to examine the difference in the energy expenditure of walking with Nordic poles versus regular treadmill walking. Hansen and Smith (2009) measured energy expenditure and self-rated comfort during uphill, horizontal, and downhill Nordic walking compared to regular walking. These three trajectories were done with both comfortable, self-selected pole lengths and short pole lengths. Self-selected pole lengths measured 115.9 ± 1.2 cm. Short pole lengths measured 108.5 ± 1.2 cm. Velocities for uphill, horizontal, and downhill walking for both Nordic and regular walking were 1.13 ± 0.04, 1.65 ± 0.06, and 1.50 ± 0.04 $m \cdot s^{-1}$. Uphill and downhill trajectories were 12 degrees. Five minute bouts of regular walking, Nordic walking with self-selected pole lengths, and Nordic walking with short poles were performed on all three trajectories. Participants were given six minute rest periods and the other conditions were performed in a counterbalanced order. Pulmonary gas exchange was measured during the last three to four minutes of each bout.

Oxygen uptake was 8.3 ± 2.5, 65.2 ± 11.5, and 54.7 ± 12.5% higher during Nordic walking with self-selected poles than ordinary walking for uphill, horizontal, and downhill conditions. Oxygen uptake was on average 67% higher for horizontal walking with Nordic poles compared to regular walking. The author attributes this to his participants using the “Ingrid Kristiansen technique” of Nordic walking. This technique utilizes longer strides which results in longer horizontal movement, long-muscle stretch shortening cycles, and long pole thrusts.

Participants chose the comfort of their arms and legs on a scale of 1 to 10. 1 represented “very, very uncomfortable” and 10 represented “very, very comfortable”. Average comfort scores for arms were 9.5, 8.7, and 8.73 for regular walking, Nordic walking with self-selected poles, and Nordic walking with short poles for the three trajectories. Average comfort scores for legs were 8.6, 8.53, and 8.17 for the same conditions. Nordic walking comfort scores are fairly high, which correlates well with the Borg scale. The moderate effort for Nordic walking is notable given the higher energy expenditures compared to regular walking. The authors attribute this difference to energy expenditure as a result of the total energy expended. While Nordic walking, load is small on both the upper and lower musculature but total energy expenditure is larger. This gives the exerciser the perception that exercise intensity is lower.

Schiffer et al. (2006) measured heart rate, lactate, and metabolic gases of fifteen, healthy, middle-aged females (44 ± 6) while Nordic walking, regular walking, and jogging on a 400 meter track. The incremental tests occurred on three different days at the same time. Nordic walking and walking speeds began at 1.2 $m \cdot s^{-1}$ and ended no faster than 2.4 $m \cdot s^{-1}$. Jogging speed began at 1.8 $m \cdot s^{-1}$ and ended with exhaustion. Movement speeds increased 0.3 $m \cdot s^{-1}$ for Nordic and regular walking for five increments. An electronic acoustic signal transmitter was placed every 50 meters on the track to provide a constant moving speed. Metabolic gases were measured by a portable indirect calorimetry system. Nordic walking, walking, and jogging speeds were compared at 1.8, 2.1, and 2.4 $m \cdot s^{-1}$.

Significant higher values of VO_2 were measured at 1.8 and 2.1 $m \cdot s^{-1}$ for Nordic walking compared to regular walking, 8% and 7%. Lactate was higher for Nordic walking than regular walking at all stages. Lactate for Nordic walking was higher than jogging and walking beginning at 2.1 $m \cdot s^{-1}$. At 2.4 $m \cdot s^{-1}$, Nordic walking lactate was 5.65 ± 1.97 compared to 3.26 ± 2.16 for jogging. Heart rates for walking and Nordic walking were higher than jogging at 2.4 $m \cdot s^{-1}$ with increased VCO_2 and lactate levels. When lactate levels of 2 $mmol \cdot l^{-1}$ were compared, VO_2 and heart rates were not different between Nordic walking and regular walking.

The study revealed higher heart rates for Nordic walking and walking at 1.8 $m \cdot s^{-1}$ compared to jogging. Higher Nordic walking lactate levels compared to jogging at 2.4 $m \cdot s^{-1}$ were attributed to the involvement of upper body musculature. Since VO_2 was the same between Nordic walking and walking at 2.4 $m \cdot s^{-1}$ but lactate levels were increased, anaerobic, type II muscle fibers were the likely factor.

Church, Earnest, and Morss (2002) compared the energy expenditure of walking with Nordic poles and without. Eleven men and eleven women walked two successive trials of 1,600 meter walking on a 200 meter track with Nordic poles and without poles in a counterbalanced manner. Heart rate, RPE, and lap times were recorded every 200 meters. Participants were informed of their lap times in the second trial so that they could closely match their first trial's time. Metabolic gases were measured continuously during the tests using portable indirect calorimetry.

The average walking speed for women and men was 3.7 ± 0.14 and 3.6 ± 0.26 $m \cdot hr^{-1}$. There was no significant difference in the time to complete the 1,600 meter trials. Combined, both sexes had a 20.6% increase in oxygen uptake when Nordic walking compared to normal walking. Average RPE for Nordic walking and normal walking was 9.2 and 8.5 on the Borg scale. Average heart rate for Nordic walking compared to normal walking was 114 and 107.6 beats per minute. Average caloric expenditure for Nordic walking compared to normal walking was 6.2 and 5.2 kcal·min^{-1}. The authors note the significant increase in oxygen uptake despite the similar RPE. The authors note that heart rates are higher than in prior studies due to the outdoor setting.

CHAPTER 3

METHODOLOGY

Purpose

The purpose of this study was to compare the oxygen uptake and heart rate responses of Nordic and treadmill walking at the same rating of perceived exertion.

Methods

Eleven college-age, average fitness individuals were recruited to participate in this study. The participants reported to the Exercise Physiology laboratory located in Davies Hall on two separate occasions. Upon arrival, participants completed an informed consent and were given an overview of their role in the research. Participant height and weight was measured to the nearest millimeter and tenth of a kilogram. Participants had the Borg RPE scale explained to them and were fitted with the Polar heart watch. They then began a 6-minute walking/jogging warm-up on the treadmill so that the researcher could assess their overall fitness and get them accustomed to the RPE scale. The warm-up began with the participants walking at a slow pace on the treadmill. Treadmill speed and grade were adjusted to 2.5 mph and 0% grade. The grade remained at 0% for the duration of the warm-up. After two minutes, the speed of the treadmill was increased to 4.5 mph and two minutes later increased to 5.5 mph. Heart rate and RPE were measured during the last 30 seconds of each speed. After the 5.5 mph stage, the treadmill speed was increased to a running speed that was "fast" for the individual participant. The participant ran at this "fast" speed for two minutes. Heart rate, RPE, and treadmill speed were recorded during the last 30 seconds of this stage. Participants then completed a cool-down and stretching for approximately five minutes while the researcher prepared the oxygen uptake measurement system. Once the system and participant were ready, the VO_2max test was begun. The participant got back on the treadmill and the mouthpiece and nose clips were put in place. Oxygen uptake, minute ventilation, heart rate, and RPE were measured throughout the test. The treadmill grade and/or speed were increased after every three minutes of exercise. The first three treadmill speeds and grades were 4.5 mph at 0%, 6.5 mph at 0%, and the "fast" self-selected running speed at 0%. After the first three stages, the treadmill speed remained the same and the treadmill was increased by 2.5% every three minutes. Participants exercised until volitional exhaustion.

Participants reported back to the Exercise Physiology laboratory and were given instructions on Nordic walking. Proper technique was explained to the participants. Participants practiced with the ExerStrider OS2 Fitness trekker AT/S poles for 15 minutes on the treadmill. Participants either Nordic walked or regular walked in a counterbalanced order. In each condition, Nordic walking and regular treadmill walking, the participants walked on the treadmill and were shown the RPE scale. Participants were told to adjust the speed of treadmill so it felt like "11" on the RPE scale. The researcher adjusted the treadmill according to the wishes of the participant and pushed the participant to 12 or 13 before readjusting the treadmill to "11". After an 11 was achieved, participants got off the treadmill and the researcher prepared the oxygen uptake measurement system. Participants then began walking at the speed that elicited an RPE of 11. Grade remained at zero throughout the test. Subjects walked for three minutes with expired gases and heart rate measured. Upon completion of the first walking condition, participants rested for five minutes. After the rest and recalibration of the oxygen uptake equipment, participants performed the second walking condition in the same manner as the first.

Measured Variables

Oxygen uptake was measured by indirect calorimetry. Expired gas flowed through a corrugated plastic tubing to a Hans Rudolph pneumotach and then 5 liter mixing chamber. Oxygen and carbon dioxide concentrations were measured with an Amtek S-3 A/1 electrochemical oxygen analyzer and a Sensor Medics LB-2 CO_2 analyzer, respectively. The analyzers were calibrated with 3.98% carbon dioxide and 15.96% oxygen calibration gases prior to testing. Percent oxygen, percent carbon dioxide, and expired gas volumes were collected continuously and averaged every 20 seconds by the Exph software and hardware (Parvomedics, Sandy, Utah) interfaced with a Dell microcomputer.

Heart rate was measured continuously throughout the testing with a Polar Vantage XL heart rate monitor. The electrodes on the elastic strap of the transmitter were wetted before being applied to the participant. The strap was placed snuggly below the pectoralis major muscle. The heart rate receiver was worn by the researcher. Heart rates were recorded by the researcher.

RPE was measured by verbal communication or by the participant pointing to their level of perceived exertion on a Borg scale chart. A 216 x 279 mm copy of the Borg scale was in view of the participant during all of the testing. Prior to testing, standardized instructions on the use of the Borg scale were read to the participants. As a part of these instructions the participants were verbally anchored by indicating that an RPE of 6 was "resting quietly" and an RPE of 20 was their "maximal exertion."

Statistics

The oxygen uptake, heart rate, and pulmonary ventilation data were analyzed with a two-way repeated measures analysis of variance. Both effects were repeated factors: condition and time. There were two conditions in the analysis: Nordic walking and regular walking. There were three time points in the analysis: minute one, minute two, and minute three. There were no interactions, so the main effect of condition for each dependent measure is reported in the results section.

CHAPTER 4

RESULTS

Introduction

The purpose of the present study was to compare oxygen uptake and heart rate response of Nordic walking and regular treadmill walking at the same rating of perceived exertion. Oxygen uptake and heart rate were monitored throughout. Heart rate response was measured every minute by the Polar Vantage XL heart rate monitor. Participants performed either Nordic or regular treadmill walking in a counterbalanced order.

Description of the Subjects

Eight male and three female, moderately active participants with a mean age of 25 ± 2.1 years participated in the present study. All participants were college-aged, moderately trained individuals. Mean stature of the participants was 176.38 ± 9.02 centimeters. Mean weight of the participants was 88.92 ± 21.56 kilograms. Mean VO_2max was 3.58 ± 1.13 $L{\cdot}min^{-1}$ and 40.51 ± 10.55 $ml{\cdot}kg{\cdot}min^{-1}$.

Treatment Effects on Oxygen Uptake

Participants Nordic or treadmill walked at an RPE of "11". Average walking speed that elicited an "11" was 3.75 ± 0.29 mph for Nordic walking. Average walking speed that elicited an "11" was 4.0 ± 0.23 mph for regular walking. Oxygen uptake was 16.60 ± 3.39, 19.18 ± 3.20, and 19.91 ± 2.73 $ml{\cdot}kg{\cdot}min^{-1}$ for minutes 1, 2, and 3 of Nordic walking. Oxygen uptake was 14.63 ± 2.74, 17.14 ± 2.51, and 18.32 ± 2.18 $ml{\cdot}kg{\cdot}min^{-1}$ for minutes 1, 2, and 3 of regular walking. The mean oxygen uptake was 18.56 ± 3.35 $ml{\cdot}kg{\cdot}min^{-1}$ for Nordic walking. The mean oxygen uptake was 16.69 ± 2.87

$ml \cdot kg \cdot min^{-1}$ for regular walking. There was a significant main effect of condition F (1,10)=6.816 (p=.0260).

<u>Treatment Effects on Pulmonary Ventilation</u>

The effect of Nordic and regular treadmill walking on pulmonary ventilation at the same RPE was measured each minute of the condition. Pulmonary ventilation was 30.33 ± 12.14, 34.05 ± 13.58, and 34.28 ± 13.57 $L \cdot min^{-1}$ for minutes 1, 2, and 3 of Nordic walking. Pulmonary ventilation was 27.64 ± 9.42, 29.05 ± 7.96, and 29.97 ± 7.10 $L \cdot min^{-1}$ for minutes 1, 2, and 3 of regular walking. The mean pulmonary ventilation was 32.89 ± 12.81 $L \cdot min^{-1}$ for Nordic walking and 28.89 ± 8.02 $L \cdot min^{-1}$ for regular walking. There was no significant main effect of condition F (1,10)=4.099 (p=.0704).

<u>Treatment Effects on Heart Rate</u>

The effect of Nordic and regular treadmill walking on heart rate at the same RPE was also examined. Heart rate was 118.2 ± 16.0, 120.2 ± 19.2, and 120.5 ± 19.0 beats per minute for minutes 1, 2, and 3 of Nordic walking. Heart rate was 112.9 ± 10.6, 114.6 ± 11.9, and 117.1 ± 12.0 beats per minute for minutes 1, 2, and 3 of regular walking. The mean heart rate was 119.6 ± 17.6 beats per minute for Nordic walking and 114.9 ± 11.3 beats per minute for regular walking. There was no significant main effect of condition F (1,10)=3.291 (p=.0997).

CHAPTER 5

DISCUSSION

The major finding of this study was that oxygen uptake was significantly higher while walking with Nordic poles compared to regular treadmill walking, yet the participants picked a speed that was slower for Nordic walking that regular walking.

The present study's findings are in agreement with a prior study done by Hansen and Smith (2009) who found a significant increase in oxygen uptake while walking on a horizontal plane with Nordic poles. The present study also is in agreement with Church, Earnest, and Morss (2002) who observed an increased oxygen uptake while walking with Nordic poles compared to regular treadmill walking.

Hansen and Smith (2009) reported oxygen uptake during uphill, horizontal, and downhill walking. They reported a 65% increase in oxygen uptake while the present study had an 8.3% increase in oxygen uptake for Nordic walking. The 65% increase is likely inflated. The authors attribute the 65% increase with Nordic walking to the "Ingrid Kristiansen technique" used by their participants. This technique calls for vigorous, long steps accompanied by long pole thrusts. The participants in the Hansen and Smith (2009) study Nordic walked at 64.7% of their VO_{2max} compared to our participants walking at 50%. Their participants regular walked at 40% of their VO_{2max} and our participants walked at 47%. Thus the intensity of exercise was similar in both conditions for the present study and very different for Hansen and Smith (2009). In light of this, it is not surprising they had very large differences in oxygen uptake.

The Nordic and regular walking speeds were also quite different between the studies. In the present study, participants were asked to subjectively choose a walking

RPE of "11". Hansen and Smith (2009) did not control the walking speed of their participants. Rather, the participants choose a speed which was "representative as much as possible of the techniques that the participant used during outdoor ordinary walking and Nordic walking." These representative walking speeds were quite different between the conditions and likely led to the large VO_2 differences and the quite different exercise intensities.

Church, Earnest, and Morss (2002) reported a 20.6% increase in oxygen uptake with Nordic poles compared to regular walking. The relative oxygen uptakes for walking and Nordic walking were 12.8 and 15.5 $ml{\cdot}kg{\cdot}min^{-1}$ compared to our finding of 16.69 and 18.56 $ml{\cdot}kg{\cdot}min^{-1}$. In the Church, Earnest, and Morss (2002) study, participants exercised outdoors, which allowed for greater propulsion with the Nordic poles. A longer, more aggressive technique was likely used due to no physical restraints which resulted in a large increase in VO_2 from regular walking to Nordic walking. It was possible to Nordic walk on the treadmill but the space was somewhat restrictive in comparison with the outdoors. The participants were instructed to keep the poles in touch with the belt, to the best of their ability. Church, Earnest, and Morss (2002) required their participants to walk around a 1,600 meter track at a comfortable velocity for one of the conditions. On their subsequent attempt, they were informed of their time at every 200 meters and advised to attempt to keep a pace that was commensurate with their prior attempt. This could result in participants exhibiting intermittent high and low velocities during testing rather than a consistent velocity. The Church, Earnest, and Morss (2002) average velocity of Nordic walking was 5.7 $km{\cdot}hr^{-1}$ compared to 6.0 $km{\cdot}hr^{-1}$ in the present study.

Church, Earnest, and Morss (2002) reported a statistically significant difference in heart rate. They reported a 6% increase from regular treadmill walking to Nordic walking, 107.6 to 114 beats per minute. The present study reported a 4.4% increase, 114.9 to 120 beats per minute. The present study reported no statistical significance. The authors suggest that heart rates may have been affected due to their participants walking and Nordic walking under different ambient conditions. Elevated temperatures will cause an increase in heart rate due to thermoregulation. RPE was also recorded for each 200 meter increment in the Church, Earnest, and Morss (2002) study. The average RPE was 8.5 for regular walking and 9.2 for Nordic walking. These lower RPEs, in comparison with the present study are consistent with the oxygen uptake data. Also, it is of interest that participants noted the higher oxygen uptake of Nordic walking by rating Nordic walking higher on the RPE scale.

To further understand the findings in the study, the influence of upper body musculature on oxygen uptake must be considered. The increased metabolic and cardiovascular demands of Nordic walking are often explained by the additional use of the upper-body musculature, which is necessary for executing the poling technique properly (Schiffer, Knicker, Dannohl, & Struder, 2009). Incorporation of the upper-body musculature requires greater total oxygen uptake which was met by increased heart rate, oxygen uptake, and minute ventilation.

The results of the study suggest that oxygen uptake of the participant is increased without the participant knowing it. This finding, which is in agreement with prior studies done on Nordic walking, suggests that Nordic walking at the same perceived exertion as regular walking yields a greater oxygen uptake. This is counter to many studies on RPE which have found that RPE and oxygen uptake are very closely related. However, an average relative oxygen uptake of 18.56 $ml \cdot kg \cdot min^{-1}$ compared to 16.69 $ml \cdot kg \cdot min^{-1}$, found in the present study, is a modest increase. In a practical sense, an individual would likely not exhibit a noticeable physiological adaptation as a result of walking with Nordic poles. Furthermore, as a percent of VO_2max, the VO_2 was 50% for Nordic walking and 47% for regular walking. These are strikingly similar and suggest the participants gauged the overall intensity of exercise very accurately with a moderate error introduced by the use of Nordic poles.

Nordic poles might assist special populations in a variety of ways. The Nordic poles engage the upper body, and may lead to an increase in upper body muscular endurance for older adults. Also, Church, Earnest, and Morss (2002) insist the poles can provide stability that may promote physical activity among older adults and those with orthopedic and balance concerns.

CHAPTER 6

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

The purpose of the present study was to examine the oxygen uptake and heart rate responses of Nordic walking and regular treadmill walking at the same RPE. The participants walked with Nordic poles and regular treadmill walked for three minutes in each condition. The participants walked at an RPE of 11, which is "light" on the Borg scale. Expired oxygen and carbon dioxide were examined to determine oxygen uptake. Heart rate was monitored with a Polar heart watch.

It was hypothesized that while walking at a speed that elicits the same RPE, Nordic walkers would have a greater oxygen uptake than regular treadmill walkers. Oxygen uptake of Nordic walking was greater ($p=.0260$) than regular treadmill walking, 18.56 ± 3.35 ml·kg·min^{-1} compared to 16.69 ± 2.87 ml·kg·min^{-1}. This result suggests walking with Nordic poles yields greater oxygen uptake even though the participants were asked to walk at the same RPE and walked at a slower speed on the treadmill.

It was also hypothesized that heart rate would be higher while Nordic walking than regular walking at the same RPE. It was believed that the greater use of upper body musculature while Nordic walking would increase heart rate. The average heart rate of Nordic walking was slightly higher (120 beats per minute) than the regular treadmill walking heart rate (115 beats per minute). There was no significant difference. The heart rate data corroborate the oxygen uptake data. Nordic walking resulted in higher physiological demands even though the participants were asked to walk at the same RPE.

Conclusion

These findings suggest that the participants of this study incorrectly perceived their exertion. Participants were asked to walk in both conditions at the same RPE. The participants Nordic walked at 50% of their VO_2max and regular walked at 47% of their VO_2max. Heart rate was also increased during Nordic walking. This disconnect between RPE and physiological indicators of exertional stress urges caution should be taken by at-risk populations who decide to exercise with Nordic poles. Unknowingly increasing oxygen uptake could create medical complications during exercise for these individuals.

Recommendations

The present researcher would like to make some recommendations for future study based on the findings of this investigation. An investigation into the heart rate effect of Nordic poles on an at-risk population should be studied. Elderly populations realize the greatest benefits of Nordic walking, because the poles will help them to be more stable. Knowledge of the heart rate and blood pressure response to Nordic walking will insure the safety of the activity and make it possible for exercise physiologists to prescribe Nordic walking for elderly participants.

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APPENDICIES

APPENDIX A

RAW DATA

Physical Characteristics of Subjects

Subject	Age (yrs)	Stature (cm)	Weight (kg)
1M	24	177.8	109.09
2M	24	177.8	118.18
3M	22	187.96	108.66
4M	29	182.88	109.55
5M	27	186.69	84.64
6F	25	160.02	58.41
7F	22	163.83	57.73
8F	26	170.82	89.55
9M	24	183.1	76.82
10M	26	171.45	68.18
11M	26	177.8	97.27

*M=male, F=female

Maximum Oxygen Uptake

Subject	($L\cdot min^{-1}$)	($ml\cdot kg\cdot min^{-1}$)
1	4.48	40.2
2	4.51	38.2
3	4.03	37.1
4	4.35	39.7
5	5.11	60.4
6	2.45	41.8
7	1.86	32.1
8	1.86	20.8
9	4.23	55.1
10	2.98	43.7
11	3.55	36.5

Oxygen Uptake of Nordic and Regular Treadmill Walking

Subject	NW ($L \cdot min^{-1}$)	W ($L \cdot min^{-1}$)	NW ($ml \cdot kg \cdot min^{-1}$)	W ($ml \cdot kg \cdot min^{-1}$)
1	2.79	2.20	25.1	19.8
2	2.52	2.16	21.3	18.3
3	2.14	2.08	19.7	19.1
4	2.61	2.15	23.8	19.6
5	1.91	1.71	22.6	20.2
6	1.26	1.15	21.4	19.6
7	1.04	1.01	18	17.5
8	1.59	1.21	17.8	13.5
9	1.51	1.65	19.7	21.5
10	1.15	1.54	16.8	22.5
11	1.64	1.69	16.8	17.3

Nordic and Regular Treadmill Walking Speeds

Subject	NW (mph)	W (mph)
1	4.0	4.1
2	3.7	3.8
3	4.1	4.3
4	4.2	4.3
5	3.7	3.8
6	3.5	3.7
7	3.6	3.8
8	3.5	3.8
9	3.9	4.2
10	3.2	4.2
11	3.8	4.0

APPENDIX B

STATISTICS

VO_2 Analysis

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value	G-G	H-F
Subject	10	360.410	36.041				
Condition	1	57.680	57.680	6.816	.0260	.0260	.0260
Condition * Subj...	10	84.625	8.462				
Time	2	144.030	72.015	68.165	.0001	.0001	.0001
Time * Subject	20	21.130	1.056				
Condition * Time	2	.656	.328	.563	.5782	.5444	.5685
Condition * Tim...	20	11.644	.582				

Dependent: VO2

Table of Epsilon Factors for df Adjustment
Dependent: VO2

	G-G Epsilon	H-F Epsilon
Condition	1.000	1.000
Time	.657	.717
Condition * Time	.808	.941

Means Table
Effect: Condition
Dependent: VO2

	Count	Mean	Std. Dev.	Std. Error
nopoles	33	16.694	2.872	.500
poles	33	18.564	3.348	.583

Means Table
Effect: Time
Dependent: VO2

	Count	Mean	Std. Dev.	Std. Error
min 1	22	15.614	3.171	.676
min 2	22	18.159	2.998	.639
min 3	22	19.114	2.547	.543

Means Table
Effect: Condition * Time
Dependent: VO2

	Count	Mean	Std. Dev.	Std. Error
nopoles, min 1	11	14.627	2.738	.825
nopoles, min 2	11	17.136	2.511	.757
nopoles, min 3	11	18.318	2.184	.658
poles, min 1	11	16.600	3.388	1.021
poles, min 2	11	19.182	3.204	.966
poles, min 3	11	19.909	2.732	.824

VE Analysis

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value	G-G	H-F
Subject	10	6282.297	628.230				
Condition	1	264.000	264.000	4.099	.0704	.0704	.0704
Condition * Subj...	10	644.054	64.405				
Time	2	122.921	61.460	18.413	.0001	.0001	.0001
Time * Subject	20	66.757	3.338				
Condition * Time	2	15.419	7.709	.882	.4295	.4183	.4295
Condition * Tim...	20	174.820	8.741				

Dependent: VE

Table of Epsilon Factors for df Adjustment
Dependent: VE

	G-G Epsilon	H-F Epsilon
Condition	1.000	1.000
Time	.848	1.004
Condition * Time	.873	1.042

NOTE: Probabilities are not corrected for values of epsilon greater than 1.

Means Table
Effect: Condition
Dependent: VE

	Count	Mean	Std. Dev.	Std. Error
nopoles	33	28.885	8.015	1.395
poles	33	32.885	12.810	2.230

Means Table
Effect: Time
Dependent: VE

	Count	Mean	Std. Dev.	Std. Error
min 1	22	28.984	10.693	2.280
min 2	22	31.552	11.157	2.379
min 3	22	32.121	10.762	2.295

Means Table
Effect: Condition * Time
Dependent: VE

	Count	Mean	Std. Dev.	Std. Error
nopoles, min 1	11	27.637	9.423	2.841
nopoles, min 2	11	29.052	7.960	2.400
nopoles, min 3	11	29.967	7.096	2.140
poles, min 1	11	30.330	12.138	3.660
poles, min 2	11	34.052	13.575	4.093
poles, min 3	11	34.275	13.516	4.075

Heart Rate Analysis

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value	G-G	H-F
Subject	10	12147.121	1214.712				
Condition	1	368.727	368.727	3.291	.0997	.0997	.0997
Condition * Subj...	10	1120.273	112.027				
Time	2	115.485	57.742	2.727	.0897	.1242	.1223
Time * Subject	20	423.515	21.176				
Condition * Time	2	15.545	7.773	1.148	.3374	.3347	.3374
Condition * Tim...	20	135.455	6.773				

Dependent: Heart Rate

Table of Epsilon Factors for df Adjustment
Dependent: Heart Rate

	G-G Epsilon	H-F Epsilon
Condition	1.000	1.000
Time	.562	.584
Condition * Time	.914	1.108

NOTE: Probabilities are not corrected for values
of epsilon greater than 1.

Means Table
Effect: Condition
Dependent: Heart Rate

	Count	Mean	Std. Dev.	Std. Error
nopoles	33	114.879	11.302	1.967
poles	33	119.606	17.562	3.057

Means Table
Effect: Time
Dependent: Heart Rate

	Count	Mean	Std. Dev.	Std. Error
min 1	22	115.545	13.522	2.883
min 2	22	117.409	15.831	3.375
min 3	22	118.773	15.596	3.325

Means Table
Effect: Condition * Time
Dependent: Heart Rate

	Count	Mean	Std. Dev.	Std. Error
nopoles, min 1	11	112.909	10.606	3.198
nopoles, min 2	11	114.636	11.935	3.599
nopoles, min 3	11	117.091	12.004	3.619
poles, min 1	11	118.182	16.005	4.826
poles, min 2	11	120.182	19.156	5.776
poles, min 3	11	120.455	18.986	5.725

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