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Comparison of treadmill and over-ground Nordic walking

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Abstract

The purpose of this study was to compare the physiological responses of Nordic walking on a specially designed treadmill and Nordic walking on a level over-ground surface. Thirteen participants completed three 1-h Nordic walking training sessions. Following the training sessions, each participant performed two 1600-m over-ground Nordic walking trials at a self-selected pace. Each participant then completed two 1600-m Nordic walking treadmill trials on a Hammer Nordic Walking XTR Treadmill®, at the mean walking speed of their two over-ground Nordic walking trials. Breath-by-breath analysis of oxygen uptake ($\dot{V}O_2$) and heart rate was performed during each trial. Caloric expenditure was calculated using the $\dot{V}O_2$. Rating of perceived exertion (RPE) was assessed at the end of each trial. We found no significant differences in physiological variables collected during the two over-ground Nordic walking trials or the two treadmill Nordic walking trials. Mean walking speed was 106.96 ± 11.49 m · min^{-1}. Mean heart rate during treadmill walking (99 ± 13 beats · min^{-1}) was 22% lower than that during the over-ground condition (126 ± 17 beats · min^{-1}). Mean $\dot{V}O_2$ and mean caloric expenditure were also lower during treadmill walking (15.18 ± 3.81 ml · min^{-1} · kg^{-1}, 0.08 ± 0.02 kcal · min^{-1} · kg^{-1}) than over-ground walking (24.16 ± 4.89 ml · min^{-1} · kg^{-1}, 0.12 ± 0.02 kcal · min^{-1} · kg^{-1}). Analysis of variance demonstrated that all variables were significantly higher during over-ground Nordic walking ($P < 0.001$). A Mann-Whitney *U*-test demonstrated that the RPE for over-ground Nordic walking was greater than that for treadmill Nordic walking ($P = 0.02$). Thus over-ground Nordic walking created a greater physiological stress than treadmill Nordic walking performed at the same speed and distance. The reason for this difference may have been the relatively narrow walking and poling decks on the treadmill, which made it difficult for the participants to place their poles correctly and maintain a consistent walking pattern. This would decrease the contribution of the arm muscles to overall oxygen consumption. In conclusion, the Hammer Nordic Walking XTR Treadmill® does not replicate the physiological stress of over-ground Nordic walking. Increasing the width of the decks could eliminate the discrepancy.

Keywords: *Pole walking, exercise intensity, caloric expenditure, rating of perceived exertion*

Introduction

In today's society, physical inactivity contributes to an increased incidence of adult obesity and diabetes (Shields & Tremblay, 2008). The causes of inactivity are numerous, but a lack of time and access to facilities are among the primary reasons given for not exercising (Shields & Tremblay, 2008). Fitness walking is a popular form of exercise to improve aerobic capacity and manage weight (Murphy, Nevill, Neville, Biddle, & Hardman, 2002; Praet et al., 2008; Schiffer et al., 2006; Walter, Porcari, Brice, & Terry, 1996). It has been reported that 81% of men and 85% of women were able to attain an adequate cardiovascular training intensity, 70% of their maximal heart rate, while walking (Porcari et al., 1987; Walter et al., 1996). However, the individuals in these studies found the speeds needed to achieve this intensity to be uncomfortable. Recent literature has focused on ways to increase the energy cost of walking without exceeding comfortable walking speeds. Studies have found that using hand, wrist, and ankle weights, and activities such as Nordic walking, can increase the energy demand of walking at a given speed (Church, Earnest, & Morss, 2002; Schiffer et al., 2006; Walter et al., 1996). Thus, achieving the recommended exercise intensity would be less time-consuming and the

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activity would likely be more attractive to the general public. This could also improve adherence once the activity was adopted.

Nordic walking was officially recognized as a fitness exercise with specific training equipment in Finland in 1997, and its popularity has spread quickly across the world (Morso, Hartvigsen, Puggaard, & Manniche, 2006). The use of poles may improve balance in people with orthopaedic or neurological conditions, which could increase physical activity in these individuals (Church et al., 2002). The increased use of the upper-body musculature provides a larger training stimulus while exercising, which is the essential physiological difference between Nordic walking and standard walking (Kukkonen-Harjula et al., 2007; Morso et al., 2006). For this reason Nordic walking has been shown to significantly increase oxygen consumption ($\dot{V}O_2$) and energy expenditure compared with standard walking (Church et al., 2002; Kukkonen-Harjula et al., 2007; Schiffer et al., 2006; Walter et al., 1996; Willson, Torry, Decker, Kernozek, & Steadman, 2001). The literature on Nordic walking refers to standard walking and over-ground walking, where standard walking is walking without poles and over-ground walking is walking on a stable, non-motorized surface.

Research has shown that Nordic walking at the same speed as standard walking leads to an increased $\dot{V}O_2$ and elevated heart rate (Church et al., 2002; Porcari, Hendrickson, Walter, Terry, & Walsko, 1997; Schiffer et al., 2006; Walter et al., 1996). Therefore, the same relative training intensity of standard walking can be achieved at a slower and more comfortable speed while Nordic walking. Schiffer et al. (2006) compared the physiological responses to over-ground Nordic walking and standard walking during an incremental field test. An electric acoustic transmitter was used to set the pace at each stage of the test. Tests started at 2.7 mph and increased by 0.67 mph every 50 m until the test was terminated at 5.4 mph. The researchers reported that at 4.0 mph the $\dot{V}O_2$ for Nordic walking was 8% greater than that for standard walking. This was a smaller difference in $\dot{V}O_2$ than previous investigators had reported when comparing Nordic walking with standard walking. For instance, Porcari et al. (1997) studied the physiological responses to standard walking and Nordic walking while on a treadmill. They found a 23% increase in $\dot{V}O_2$ and a 16% increase in heart rate when Nordic walking compared with standard walking at a self-selected speed (women: mean 3.8 mph, range 3.0–4.5 mph; men: mean 4.3 mph, range 3.9–4.8 mph) for 20 min. One explanation for the difference between the results reported by Schiffer et al. (2006) and Porcari et al. (1997) is that participants walked a shorter distance during the incremental tests. In addition, incremental and endurance protocols create different physiological demands and therefore cannot be used to provide an adequate comparison between the physiological demands of standard walking and Nordic walking. One advantage of the treadmill Nordic walking technique used by Poracari's group is that the participants maintained a consistent walking speed between trials. However, Church et al. (2002) noted that the narrow deck on the treadmill would necessitate changes in pole-planting technique and therefore treadmill Nordic walking in the study of Porcari et al. (1997) was not truly representative of the over-ground technique used by most people who undertake Nordic walking. As a result, Church et al. (2002) assessed the physiological responses associated with Nordic walking and standard walking over ground. They found a 20.6% increase in $\dot{V}O_2$ and a 6% increase in heart rate when Nordic walking compared with standard walking at a self-selected speed (women: mean 3.7 ± 0.14 mph; men: mean 3.6 ± 0.26 mph) over a 1600-m course. The researchers ensured that the walking speed for Nordic walking and standard walking was the same, while over-ground walking on an outside track permitted the participants to use a proper pole-planting technique when they were Nordic walking.

Laboratory-based exercise testing using modalities such as treadmills and cycle ergometers is considered the "gold standard" for exercise testing (Ambrosino, 1999). This type of testing permits control of variables such as wattage, speed, incline, and walking surface, and until recently it was the only way to measure $\dot{V}O_2$. It would be useful to be able to assess Nordic walking under these controlled conditions; however, as Church et al. (2002) pointed out, the poling technique on a standard treadmill is not representative of that used by most people in recreational over-ground treadmill walking . Recently, treadmills with separate decks for Nordic walking poles have been designed. It is possible that these will facilitate a more authentic poling technique and therefore accurately simulate over-ground Nordic walking. The purpose of this study was to compare the physiological responses of over-ground Nordic walking and treadmill Nordic walking using a specially designed treadmill with designated poling decks. The results from studies that have compared the metabolic costs of treadmill and over-ground walking are equivocal (Murray, Spurr, Sepic, Gardner, & Mollinger, 1985; Pearce et al., 1983; Waters, Lunsford, Perry, & Byrd, 1988; Waters & Mulroy, 1999). Therefore, we hypothesized that Nordic walking over ground would produce similar physiological responses as treadmill Nordic walking using specially designed decks to replicate a typical Nordic walking poling technique.

Methods

Participants

The participants for this study were drawn from a sample of convenience consisting of university students aged 23–28 years. The investigation was approved by the local Research Ethics Board, in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 1983. Written and informed consent was obtained from 13 participants (5 males, 8 females). The participants completed the Physical Activity Readiness Questionnaire (PAR-Q) (Public Health Agency of Canada, 2010) and were excluded from the study if they had a positive response to any of the questions. Participants were also excluded from the study if they had any known cardiovascular, musculoskeletal, or neurological conditions that would prevent them from completing the exercise testing safely, if they were unable to Nordic walk 1600 m, or if they failed to comply with the experimental protocol. All participants received three 1-h training sessions by a Nordic walking coach who ensured that they were able to maintain a consistent Nordic walking technique for 5 km. Participants were excluded from the study if they were unable to achieve this criterion.

Procedures

All participants adhered to the ACSM pre-testing protocol and refrained from eating, smoking, and drinking alcohol or caffeine for 3 h before the test as well as abstaining from strenuous physical activity the day of the test (Thompson, 2010). Demographic data for each participant were collected before the first over-ground walking test. On the same day, participants completed two over-ground walking sessions. The average self-paced walking speed on these two tests was used as the walking speed for the treadmill sessions. Each participant completed an approximately 30-min orientation to treadmill Nordic walking on a Hammer Nordic Walking XTR Treadmill® (Hammer Sport AG). During the orientation, participants began by walking slowly to become comfortable with the technique. The speed was gradually increased to the trial walking speed, which was maintained for 15 min. This orientation took place no less than 3 days and no more than 10 days after the over-ground sessions. Participants completed their two treadmill Nordic walking data collection trials the day after the orientation. The two data collection trials under each condition were separated by a rest period that restored heart rate to within 5 beats $\cdot$ min^{-1} of their resting heart rate. Two trials were chosen to account for the learning effect that is present in other field tests of aerobic endurance, such as the shuttle walk test and the 6-min walk test (Brown & Wise, 2007). Each participant's data collection trials took place at the same time of day and all trials took place in a 3-h window around midday. The temperature during all testing ranged from 18 to 22°C. The treadmill Nordic walking trials were conducted in a well-ventilated laboratory.

Physiological data were collected using the Oxycon Mobile® (VIASYS Healthcare, GmBH, Germany), a portable metabolic unit that measures gas exchange breath-by-breath and is attached to the body using a vest system. The participants wore a face mask that was connected to a flow sensor (Hans Rudolf, Inc., Kansas City, MO) that measures ventilation. A sampling line directed expired air to a sensor unit that measures O_2 and CO_2 concentrations using a microfuel cell and thermal conductivity, respectively. The system was calibrated after a 30-min warm-up. Calibration consisted of a two-point (0.2 and 2.0 L $\cdot$ s^{-1}) air flow calibration using the automatic flow calibrator, gas calibration against a certified gas mixture of 5% O_2, 16% CO_2, and 79% N_2, and determination of measurement delay time. The validity and reliability of this system has been reported elsewhere (Rosdahl, Gullstrand, Salier-Eriksson, Johansson, & Schantz, 2010). An integrated Polar® (Polar T61, Kempele, Finland) heart rate receiver was used to measure heart rate. All data were sent to a base station connected to a computer that displayed the data in real time. Data were automatically stored on the computer for future analysis.

Over-ground Nordic walking

Participants walked four 400-m laps on a level outdoor track at their comfortable walking pace. The test was preceded by a one-lap warm-up at the comfortable walking speed identified during the Nordic walking training sessions. Heart rate and $\dot{V}O_2$ were measured, when standing, during the 5-min rest prior to beginning the test and for the duration of the walk. Rating of perceived exertion was assessed before beginning the test and at the end of each lap using standardized instructions and the Borg 6–20 scale (Borg, 1970). The time to complete each lap was recorded. Participants were told that they would not receive encouragement during the test.

Treadmill Nordic walking

The Hammer Nordic Walking XTR Treadmill® (Hammer Sport AG) consists of a 14-inch walking deck and two 5-inch poling decks. Participants had a 30-min practice session followed by a 30-min rest before beginning the data collection trials.

The practice session was followed by a 4-min warm-up at the trial walking speed. During the data collection trials, speed was increased over a 30-s period until the participants were walking at the average walking pace from the two over-ground walking trials. Participants walked at this speed for 15 min. Data collection was the same as that described for the over-ground trials. The event marker option was used to identify the times that corresponded to lap completion times in the over-ground trials. Rating of perceived exertion was recorded at these times.

Data analysis

The Oxycon Mobile® works on a breath-by-breath basis. The first 30 s of each trial's data was removed before data processing to account for the time it could take the partyicipants to reach their comfortable walking speed. Data collection was stopped at the end of the 1600-m walk or the treadmill walking time. All data from 30 s to the end of the trial were used to calculate the parameters presented.

The mean caloric expenditure ($kcal \cdot min^{-1} \cdot kg^{-1}$ and $kcal \cdot min^{-1}$) for each participant in each condition was calculated using the mean $\dot{V}O_2$ from the trial and the method described by the ACSM (Thompson, 2010). A general linear model was used to perform an analysis of variance to compare the differences in heart rate, $\dot{V}O_2$, and caloric expenditure in each condition. Condition and trial were treated as fixed factors and participants as a random factor. Analysis revealed no significant differences between walking trials during treadmill Nordic walking or over-ground Nordic walking for any of the variables, and therefore the mean and standard deviation for a particular variable were calculated using the observations from Trial 1 and Trial 2 (Table II). A Mann-Whitney *U*-test was used to analyse the RPE scores as they are considered non-parametric data. All statistical analysis was performed using the Minitab15® Statistical Software Package (State College, PA). Statistical significance was set at $P < 0.05$.

Results

Thirteen participants completed the study. Baseline characteristics for the subjects are presented in Table I. The average walking speed was 107 ± 11.49 $m \cdot min^{-1}$, with a range of $98 - 131$ $m \cdot min^{-1}$. The mean walking time was 15 min and 21 s $\pm$ 36 s, with a range of 14 min and 11 s to 17 min and 55 s.

Analysis of variance demonstrated statistically significant differences between the conditions for heart rate ($F_{1,35} = 88.2$; $P < 0.001$), $\dot{V}O_2$ ($F_{1,35} = 102.5$; $P < 0.001$), and caloric expenditure ($F_{1,35} = 118.6$; $P < 0.001$). The mean value ($\pm$ standard deviation) for each variable, during each condition, is presented in Table II. Heart rate was 22% lower during treadmill Nordic walking than in the over-ground condition. Similarly, $\dot{V}O_2$ was 37% less and caloric expenditure was 33% less during treadmill Nordic walking. The mean caloric expenditure during treadmill Nordic walking was 0.08 ± 0.02 $kcal \cdot min^{-1} \cdot kg^{-1}$ and during over-ground Nordic walking it was 0.12 ± 0.02 $kcal \cdot min^{-1} \cdot kg^{-1}$. In contrast, at the end of the over-ground Nordic walking trial, the RPE (median 12, range 8–13) was significantly higher than at the end of the treadmill Nordic walking trials (median 10, range 7–12; Mann-Whitney *U*-test: $P < 0.02$).

Discussion

The purpose of this study was to compare the physiological responses of over-ground Nordic walking with those of treadmill Nordic walking, using a specially designed treadmill with designated poling decks. We hypothesized that treadmill Nordic walking would show similar physiological responses as

Table I. Summary of participant demographics

Participant	Sex	Age (years)	Mass (kg)	Height (cm)	Body mass index ($kg \cdot m^{-2}$)
1	F	24	76	1.82	22.94
2	M	23	82	1.80	25.31
3	F	24	62	1.63	23.34
4	M	23	84	1.85	24.54
5	M	23	81	1.85	23.67
6	F	23	67	1.69	23.46
7	F	27	58	1.73	19.38
8	F	24	67	1.73	22.39
9	F	25	60	1.68	21.26
10	M	28	82	1.75	26.78
11	F	24	50	1.58	20.03
12	M	24	82	1.80	25.31
13	F	24	65	1.77	20.75
mean $\pm s$	M = 5 F = 8	24.0 ± 1.6	70.0 ± 11.3	1.74 ± 0.08	23.00 ± 2.21

Table II. Heart rate, oxygen consumption, and caloric expenditure for treadmill and over-ground Nordic walking (mean ± *s*)

Variable	Treadmill walking	Over-ground walking	*P*-value
Heart rate (beats · min^{-1})	99 ± 13	126 ± 17	< 0.001
$\dot{V}O_2$ (ml · min^{-1} · kg^{-1})	15.18 ± 3.81	24.16 ± 4.89	< 0.001
Caloric expenditure (kcal · min^{-1} · kg^{-1})	0.08 ± 0.02	0.12 ± 0.02	< 0.001
Respiratory exchange ratio	0.89 ± 0.13	0.84 ± 0.19	0.480

RER = respiratory exchange ratio.

over-ground Nordic walking and therefore could be an alternative training modality. In Canada, walking is the leisure-time physical activity practised by the highest percentages of men and women and is done more frequently than other activities (Statistics Canada, 2010). Winter conditions and the large number of rural communities in the country can make it difficult to walk enough to meet recommended activity standards. Many investigations have demonstrated that Nordic walking increases $\dot{V}O_2$ more than standard walking under the same conditions (Church et al., 2002; Kukkonen-Harjula et al., 2007; Schiffer et al., 2006; Walter et al., 1996; Willson et al., 2001). Furthermore, at the same exercise intensity, Nordic walking is perceived to be less stressful than standard walking, which could increase exercise adherence. Thus Nordic walking could be a means of increasing physical activity and improving health.

The most recent guidelines in Canada (Public Health Agency of Canada, 2003) and the United States (United States Department of Health and Human Services Office of Disease Prevention and Health Promotion, 2008) recommend that adults should do at least 150 min of moderate-intensity aerobic exercise a week to obtain substantial health benefits. These benefits include decreased mortality (Manini et al., 2006; Stefanick et al., 1998); a decrease in the incidence of heart disease (Hambrecht et al., 1993; Schuler & Hambrecht, 1996), diabetes (Church et al., 2004; Sui et al., 2008), and cancer (McTiernan et al., 2003); improved cognition (Abbott et al., 2004); and a reduction in depressive symptoms (Kamphuis et al., 2007). Unfortunately, most people do not meet these guidelines (Statistics Canada, 2010; United States Department of Health and Human Services Centers for Disease Control and Prevention, 2010). Many people find moderate-intensity exercise uncomfortable or that this exercise intensity aggravates existing musculoskeletal problems (Elley, Dean, & Kerse, 2007). Nordic walking is an option for overcoming these barriers. Church et al. (2002) reported that Nordic walking increased $\dot{V}O_2$ by 20.6% compared with over-ground walking and that this increase was not associated with a significant increase in perceived exertion. These authors also suggested that using poles might reduce stress on lower-extremity joints. Nordic walking poles improve walking stability (Jacobson, Caldwell, & Kulling, 1997), which could reduce the risk of falling, making physical activity safe for older individuals and others with poor balance. The associated improvement in self-efficacy should increase adherence to physical activity guidelines (Steptoe, Rink, & Kerry, 2000). Frequently, climate and constraints associated with having to travel to the gym or fitness centre are cited as reasons for inconsistent exercise habits (Elley et al., 2007; Steptoe et al., 2000). Treadmills at home and in fitness centres are often used to overcome these impediments. Therefore, we wanted to determine whether Nordic walking on a treadmill specially designed for this activity would be a valid representation of over-ground Nordic walking.

Our results demonstrate that $\dot{V}O_2$, caloric expenditure, and heart rate were significantly lower during treadmill Nordic walking compared with over-ground Nordic walking, demonstrating a lower workload during the treadmill walking condition. Manini and colleagues (2006) reported that in older adults an increase of 287 kcal · day^{-1} in free-living activity energy expenditure was associated with a 32% lower risk of mortality after adjusting for age, sex, race, study site, weight, height, percentage of body fat, and sleep duration. The participants in the current study expended an average of 8.62 kcal · min^{-1} during over-ground Nordic walking and 5.42 kcal · min^{-1} when Nordic walking on a treadmill. To achieve the mortality benefit noted above from the addition of Nordic walking exercise alone, individuals would have to over-ground Nordic walk for 33 min and treadmill Nordic walk for 53 min. The 59% increase in caloric expenditure during over-ground walking could affect exercise behaviour because it is likely that adherence to a shorter exercise programme would be better than that to one with longer time commitment. While the difference between the RPE for the two conditions was statistically significant, it may not be clinically meaningful. Using the Borg 6–20 scale, participants rated their exertion as 11 or "light" during over-ground Nordic walking and 9 or "very light" during treadmill Nordic walking. These differences in perceived exertion may not be large enough to change a person's participation in an exercise programme. On the other hand, individuals would have to treadmill walk at a significantly higher RPE to achieve the caloric expenditure obtained during over-ground Nordic walking. That degree of exertion could be uncomfortable and perhaps negatively affect exercise adherence.

The Hammer Nordic Walking XTR Treadmill® was designed to replicate a typical over-ground Nordic walking technique. The poling decks are designed to stop with pole contact to allow for a pushing force equivalent to over-ground Nordic walking. Therefore, we believed that the two conditions (over-ground Nordic walking and treadmill Nordic walking) would be equivalent in terms of workload, energy expenditure, and sense of exertion. However, over-ground Nordic walking proved to be more challenging than the same activity performed on the Hammer treadmill. Our observations and participant feedback suggest that differences in poling techniques during the two conditions were responsible for the differences we observed. Participants often placed their poles on the walking deck or between the walking and poling decks, which disturbed the rhythm of the movement and decreased the arm force used. Previous studies have reported that use of the upper extremities is the essential difference contributing to the increase in energy expenditure that is typically found when comparing Nordic walking and over-ground walking (Kukkonen-Harjula et al., 2007; Morso et al., 2006). Thus we believe that decreased use of the upper extremities lowered heart rate and energy expenditure during treadmill Nordic walking. It would also contribute to the lower RPE reported during treadmill walking.

The participants in the present study were young, healthy, active novice Nordic walkers. They were trained by a certified Nordic walking instructor who also ensured that all participants were able to maintain a consistent over-ground Nordic walking technique before beginning data collection. Therefore, we are confident that the participants' walking technique was reproducible during over-ground walking. The participants received a much less intensive orientation to treadmill Nordic walking, which may have accounted for the difficulties they noted during the treadmill sessions. It is possible that more rigorous treadmill Nordic walking training would improve poling technique and affect the workload on the treadmill. It is also possible that more experienced Nordic walkers would be able to maintain a consistent walking style on the treadmill and therefore achieve an energy expenditure that equalled that of over-ground walking. Future research using a more diverse population that included older as well as experienced Nordic walkers and individuals of a wide range of fitness would be more representative of the ability of treadmill Nordic walking to mimic over-ground Nordic walking (Gillette & Gillis, 2005).

Nordic walking is a valuable exercise and has several advantages over standard walking or running. For some time, treadmills have been used as an alternative to walking outside when weather, transportation or location make the latter difficult. The Hammer Nordic Walking XTR Treadmill® was designed to allow users to reproduce an over-ground Nordic walking technique and presumably the physiological workload associated with this activity. Our research demonstrates that the treadmill design did not result in consistent pole placement typical of the over-ground Nordic walking technique, which may have been responsible for the difference in energy expenditure in the two Nordic walking conditions. Hopefully these design issues can be resolved so that more people will be encouraged to learn Nordic walking and to use this exercise consistently. With the proper treadmill design, the health benefits of treadmill Nordic walking could be more fully exploited.

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