Physiological responses to moderate and high arm work during walking with poles

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Abstract
Walking with poles or Nordic Walking (NW) is considered an activity with higher energy cost than simple walking (W). The aim of the study was to assess the effect of arm work intensity on energy expenditure during walking with poles in 14 active males. Oxygen consumption was used to assess energy cost during W and NW with moderate and high arm work intensity. NW with low arm work was only equal in demand as walking without poles. However, NW with high arm work or active propulsion produced large increases in the oxygen uptake of 5.4 and 4.1ml.min^{-1}.kg^{-1} at 0 % and 10% slope, respectively. The study showed that arm work intensity is one of the key factors influencing the energy cost of NW. The results may be considered by physical trainers or therapists in developing NW program prescription. The proper NW technique with active arm propulsion should be performed when seeking an increase in activity energy cost.

Key words
Nordic walking, energy expenditure

Introduction

The practice of regular physical activity (PA) is associated with improved mental and physical health (Garber et al., 2011). Walking is the most common PA in adults (Rafferty, Reeves, McGee, & Pivarnik, 2002) and the related health benefits have already been demonstrated (Boone-Heinonen, Evenson, Taber, & Gordon-Larsen, 2009). Walking is a natural locomotion, suitable for all age categories; it is materially not-demanding and easily practised outdoors and indoors. Walking with poles, or Nordic walking (NW), originated in Finland and its popularity has increased considerably over the past 20 years (INWA, 2010). Church et al. (2002) documented higher upper muscle limb activity when using poles, rather than simple walking, and therefore higher oxygen consumption without significantly increased perceived exertion (Porcari, Hendrickson, Walter, Terry, & Walsko, 1997). In this way, NW may represent an attractive activity especially for lower fitness or overweight persons who seek an increase of exercise intensity. The differences in energy cost between walking and NW mentioned in the literature vary between 7 - 23% (Church, et al., 2002; Dechman, Appleby, Carr, & Haire, 2012; Figard-Fabre, Fabre, Leonardi, & Schena, 2009; Hansen & Smith, 2009). This variability may be accounted for by the speed of locomotion, the pole length, the type or inclination of the terrain. The highest differences were stated during higher speeds of walking or field testing (Church, et al., 2002; Porcari, et al., 1997) where higher arm propulsion might have been expected. Our assumption was that the active propulsion or arm work during the locomotion will play a key role in energy cost of NW.

Aim

The aim of the study was to assess the effect of arm work on energy expenditure during NW.

Methods

Participants

The research sample consisted of 14 aerobically active males (24.1 ± 1.8 yrs, 74.3 ± 6.4 kg, 179.1 ± 5.4 cm). All participants were physical education students and familiar with Nordic walking. The study was approved by the local Human Ethics Board.

Procedure

For the test procedure, participants completed, after familiarisation, 2 x 3 (inclination x condition) different trials in one test session. The walking and NW was tested on a treadmill (Quasar, H/P/Cosmos, Germany) at 0 % and 10 % inclinations at a speed of 6 km.h^{-1}. The conditions represented walking, NW with moderate arm work and NW with high arm work. Each stage lasted for four minutes starting at 0 % by walking, followed by walking with moderate and then high arm work. The intensity of arm work was set on a subjective scale 1-5, where moderate arm work corresponded to 1-2 and high arm work to 4-5. All walkers received a 4 minute rest before undertaking the same procedure at 10 % inclination. The length of poles was adjusted specifically for each subject to an appropriate length in which the elbow was flexed at 90° while the pole was held in a vertical position and in contact with the ground.

Measurement of energy cost

Minute ventilation (V_E), oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were measured during the treadmill tests by a portable breath-by--breath indirect calorimetry system (MetaLyzer, Cortex Biophysic, Germany). Before each test, gas and volume calibration was performed according to the manufacturer's guidelines. The volume calibration was performed using a known 3L syringe, and gas calibration was performed with a known gas mixture of 15% O_2 and 5% CO_2. Data was averaged over 20 s intervals; the mean of the last minute from each stage and the highest values from the maximal test were analysed. RER was computed by dividing measured CO_2 by measured O_2. HR was monitored by the MetaLyzer using a Polar heart transmitter belt (Polar Electro OY, Finland).

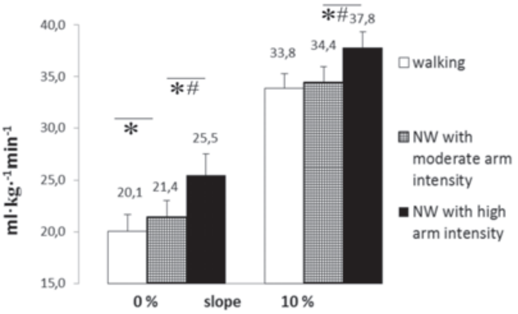
Statistical analysis

The normality for all variables was tested by one sample Kolmogorov-Smirnov goodness of fit. All data showed normal distribution. Descriptive statistics (means and standard deviations) were used to characterize the physiological responses during walking and NW. The differences between walking, NW with moderate and high arm work were assessed by repeated measure ANOVA and pairwise comparisons between walking and NW conditions. The statistical significant differences were considered at $P \leq 0.05$. 'Practical' differences in relative VO2 were set to at least 2 ml.min^{-1}.kg^{-1}.

Results

At 0 %, we observed statistically significant ($p < 0.001$) but 'practically' not significant increase (↑ 1.3 ml.min^{-1}.kg^{-1}) in the oxygen consumption between walking and NW with moderate arm work. On the other hand, we found significant ($p < 0.001$; ↑ 4.1 ml.min^{-1}.kg^{-1}) increase between NW with moderate and high arm work (Figure 1). At 10 %, we observed no significant ($p = 0.14$; ↑ 0.5 ml.min^{-1}.kg^{-1}) increase in the oxygen consumption between walking and NW with moderate arm work but significant ($p < 0.001$; ↑ 3.4 ml.min^{-1}.kg^{-1}) increase between NW with moderate and high arm work (Figure 1).

Figure 1. Oxygen consumption during walking (W), Nordic walking (NW) with moderate and high arm work in two inclinations (0°, 10°). * indicates statistically significant differences ($p < 0.001$) and # differences higher than 2 ml.min^{-1}.kg^{-1} .



There was a significant effect ($p < 0.001$) of inclination on VO2 but no significant interaction between the slope and walking conditions was found. The other physiological parameters are presented in Table 1. The data confirms physiological increases with the pole conditions and inclination, as described before.

Table I. Mean (± standard deviation) heart rate (HR), oxygen uptake (VO_2) and respiratory exchange ratio (RER) during walking (W), Nordic walking (NW) with moderate and high arm work in two inclinations (0°, 10°)

		HR (beats . min^{-1})	VO_2 (l . min^{-1})	V_E (1 . min^{-1})	RER
0%	W	100 ± 10	1.49 ± 0.13	36.2 ± 4.8	0.91 ± 0.05
	NW moderate arm work	104 ± 10	1.59 ± 0.17	39.6 ± 4.3	0.93 ± 0.04
	NW high arm work	117 ± 11	1.89 ± 0.17	48.5 ± 4.9	0.94 ± 0.05
10%	W	131 ± 10	2.51 ± 0.18	55.0 ± 5.8	0.89 ± 0.04
	NW moderate arm work	137 ± 10	2.55 ± 0.23	58.7 ± 5.3	0.92 ± 0.03
	NW high arm work	149 ± 10	2.80 ± 0.22	68.6 ± 6.8	0.95 ± 0.04

Discussion

The purpose of the current study was to assess the effect of arm work during walking with poles on energy expenditure. The results were compared to walking without poles. The participants were recruited among physical education students which makes the results hard to generalizable for elderly and physically inactive populations. The testing procedure was performed on a treadmill which can decrease the measured values compared to over-ground walking (Dechman, et al., 2012). Nevertheless, the treadmill enabled the use of different intensities of arm work and the participants' NW technique was not compromised by the treadmill.

To our knowledge, only one previous study has compared different arm work in NW (Jensen et al., 2011). Jensen et al. (2011) investigated if an increase load transmitted through arms to the poles could reduce the knee joint compression force during level walking with poles. A force 2.4 higher than normal pole force did not lead to a reduction in the knee joint compressive force.

Our hypothesis was that the arm work intensity is the main contributor to the higher oxygen uptake in NW, as described in the literature (Church, et al., 2002; Porcari, et al., 1997; Rodgers, Vanheest, & Schachter, 1995; Schiffer et al., 2006). In the current study, the differences between walking and NW with moderate arm work during level walking were 6% and roughly corresponded to differences of 8% between walking and NW at a speed of 1.8 $m \cdot s^{-1}$ (6 $km \cdot h^{-1}$) in the Schiffer et al. study (2006). On the other hand, the differences between walking and NW with high arm work during level walking were 27% and were in line with the values reported by Church et al. (2002) who found a 20,6% difference between walking and NW at a speed of approx. 1.6 $m \cdot s^{-1}$ (5.8 $km \cdot h^{-1}$) and also Porcari et al.'s study (1997) who found a 23% difference between walking and NW at a speed of approx. 1.69 $m \cdot s^{-1}$ (6.1 $km \cdot h^{-1}$). This data shows that variances of higher oxygen uptake in NW may be explained by the intensity of arm work.

The speed of 6 $km \cdot h^{-1}$ was selected because the participants were unable to perform active propulsion with the poles at lower walking speeds. Therefore, with lower arm work, there may be not sufficient differences in oxygen consumption between walking and NW. This hypothesis is supported by the study of Schiffer et al. (2006) who stated non-significant difference in oxygen consumption between walking and NW at speeds lower than 6 $km \cdot h^{-1}$. Nevertheless, the speed of 6 $km \cdot h^{-1}$ may represent excessive intensity for middle aged, elderly or inactive populations, and this population would not benefit from using poles to increase energy cost of PA (Fritschi, Brown, Laukkanen, & van Uffelen, 2012; Kukkonen-Harjula et al., 2007). Figard-Fabre et al. (2009) found, in obese women, that the use of NW poles increased physiological responses at a speed of 4 $km \cdot h^{-1}$. However, although, the increase (12%) in VO_2 during level NW was found to be statistically significant it was smaller than 2 $ml \cdot min^{-1} \cdot kg^{-1}$ which represents only a normal fluctuation of oxygen uptake. The main limitation of the study is the choice of active male participants, which make the results difficult to generalize to a broader population. Inactive, elderly and overweight persons may not be able to achieve the speed of 6 $km \cdot h^{-1}$ where active arm propulsion can be performed.

Conclusions

The study showed that arm work intensity is one of the key factors influencing the energy cost of NW. NW with low arm work was only equal in demand as walking without poles. However, NW with high arm work or active propulsion produced large increases in the oxygen uptake of 5.4 and 4.1 $ml.min^{-1}.kg^{-1}$ at 0 % and 10% slope, respectively. The results have implications for trainers or therapists in prescribing NW programmes. The proper NW technique with active arm propulsion should be performed when seeking an increase in activity energy cost.

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