Original Paper

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Energy expenditure of nordic walking and conventional walking assessed by accelerometer

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Summary

Study aim: the objective was to assess and compare the energy expenditure (EE) and exercise heart rate (EHR) during Nordic Walking (NW), and conventional walking (W) in physical education and tourism/recreation university students.
Material and methods: a total of 53 women and 65 men, students at the Academy of Physical Education in Katowice, and Polytechnic in Opole, in Poland, were investigated to assess the EE of Nordic Walking and conventional walking, and to measure the EHR, a uniaxial accelerometer – Caltrac Monitor, and a pulsometer – Polar RS 400 SD were used. After a standard warm-up, the participants (joined group) were marching with poles for 30 minutes, at a speed regulated by the group's leader, who used footpod's indications: 5.5–6.5 km/h – in Katowice, and 7.5–8.5 km/h – in Opole. After a break, during which the participants' heart rate decreased below 100 bpm, the above actions and measurements were repeated, during normal walking.
Results: energy expenditure during Nordic Walking (EE NW), expressed in kcals and METs, was in women and in men, at both analyzed speeds, significantly higher ($p < 0.05$) than during conventional walking (EE W). EHR was higher during NW, compared to W, and the statistically significant differences were revealed both in female's and male's groups.
Conclusions: our study data have shown that EE and EHR during Nordic Walking, have been significantly higher than during conventional walking, regardless of the moving speed and gender. NW might present a useful modality in prevention of hypokinetic disorders.

Key words: Nordic Walking – Energy expenditure – Accelerometer – Caltrac Monitor

Introduction

Over the last few decades, Nordic Walking (NW) has become one of the most popular forms of recreational exercises, among different age groups, including elderly people. This tendency has also been evident in Poland that may be a representative country of Central Europe. Natural, easy to master movements and reasonable cost of necessary equipment contribute to successful practicing of this activity. In addition, NW does not require any difficult to learn technical skills nor special facilities [5]. NW is characterized by the use of two walking poles, and long steps combined with regular walking [22]. In the elderly population, NW increases safety by providing additional points to support balance, and thus, reducing risk of falls. NW might be a convenient form of adapted physical activity, recommended for persons with specific health needs, or different medical problems, especially the ones of hypokinetic etiology [20]. A phenomenon of the NW popularity has also become a subject of various scientific studies, focusing on its three main aspects: health, fitness, and sport [20, 22]. With regard to health-oriented targets, the NW usefulness, as a rehabilitation tool has been investigated in the context of respiratory tract diseases [2], cardiovascular diseases [15], metabolic disorders [6, 8, 9], and Parkinson's disease [28].

Numerous experimental studies have analyzed the impact of NW on somatic and functional parameters, in different age groups [16, 18, 19, 21, 29]. In fitness studies, involving participants with a higher level of physical agility, the energy expenditure (EE) during NW, performed at different speeds, was compared to regular marching, and jogging or running, at the same speed, by using different methodological designs and research tools [3, 6, 11, 14, 25]. In sport studies, involving Physical Education students (the mean age 22 years), including 50% of cross-country skiers, oxygen consumption during walking with

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and without poles, on a treadmill (at 17% slope), at three different speeds (5.5, 6.0, and 6.5 km/h) were compared. These studies have shown that the oxygen consumption was significantly higher during walking with poles [12].

The aim of this study was to assess and compare the energy expenditure (EE) and exercise heart rate (EHR) during NW, and conventional walking (W), at a speed 6.0 and 8.0 km/h, in female and male volunteers-participants (students at The Physical Education, and Tourism and Recreation Departments, of two Polish universities, in Katowice and Opole).

Materials, methods, and study organization

The study was approved by the Bioethics Committee for Scientific research at the The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, in May of 2011.

A total of 118 students-volunteers, including, 53 (21 female and 32 male) from the Academy of Physical Education in Katowice – group I and 65 (32 female and 33 male) from the Department of Physical Education and Physiotherapy, at Polytechnic in Opole – group II were investigated.

The measurements were conducted at Kosciuszko Park, in Katowice, and on the banks of Odra River, in Opole, at tracks (asphalted). The study participants received instructions with regard to basic techniques of marching with poles, during 8 hours of mandatory practice, lead by qualified instructors. The students – volunteers, who mastered the NW technique, were enrolled into the study, after giving their written informed consent to participation.

In order to assess EE of Nordic Walking and conventional walking, a direct observation, based on registration of kinematical parameters of the movement acceleration was used. A uniaxial accelerometer – Caltrac Monitor (Muscle Dynamics, Inc., Torrance, CA, U.S.), which is an electronic device that registers locomotive body movements (acceleration) and converts it to kilocalories (kcals), (taking into account the participant's age, gender, body mass and height, which were coded to the device's memory), was used as a measurement tool. It was carried in a pocket (attached to the hip belt) by all the participants [17]. It has been considered that accelerometers serve as appropriate tools for EE evaluation during marching at various speeds (despite questioning their usefulness, by some studies, in which EE of different types of physical activity was measured) [4, 16].

In study groups from Katowice and Opole sites, the examination was conducted in one day, and all measurements were made in the morning. Following a standard warm-up, the participants (joined group) were marching with poles for 30 minutes, at a speed regulated by the group's leader, who used footpod's indications: 5.5–6.5 km/h – in Katowice, and 7.5–8.5 km/h – in Opole. After 30 minutes, the participants' exercise heart rate (EHR) was measured, using a pulsometer (Polar RS 400 SD).

EE values were simultaneously read from the accelerometer. After a 20-min. break, during which the participants' heart rate decreased below 100 bpm, the above measurements were repeated – this time – during conventional walking (W). Field testing conditions (e.g., ambient temperature, wind force, air humidity, and psychophysical condition of the participants) remained relatively stable. That allowed to obtain reliable data for comparative analyses of EE, during both NW and W.

These numerical data were calculated per one hour of exertion, by multiplying the EE of both NW and W (the two walking activity forms being compared) by two (kcals). The obtained values were also calculated per kilogram of body mass (kcals/kg/h) that allowed to assess the intensity of exertion, expressed in METs.

Statistical analysis

Statistical analysis was performed using Statistica v. 10 software (StatSoft Inc., USA). Data are presented as means ($\overline{x}$) and standard deviations (SD). The significance of differences in the measured parameters (EE and EHR) in women and men was assessed using the *U*-Mann-Whitney test. Differences between groups were calculated by non-parametric *Z*-Wilcoxon's rank-sum test (for comparison of the EE during NW – with poles, and W – without poles). Each analysis was done separately for women, and for men, from Katowice and Opole study sites. The significance level was set at 5% error.

Results

Baseline data in table 1 present characteristics of the study participants. There was a statistically significant differences ($p < 0.05$) in the age and body height between participants from Katowice and Opole. Body mass, BMI (somatic parameters) and resting heart rate (physiological parameter) of the participants from Katowice and Opole sites were similar, and no statistically significant ($p \geq 0.05$) differences between them were reported (table 1).

With regard to a higher body mass in men, compared to women, a significantly higher EE ($p < 0.05$) of walking activity forms, expressed in kcals was reported (except conventional walking at a speed 7.5–8.5 km/h) (fig. 1). In contrast, the differences in EE of NW, expressed in METs between women and men were no statistically significant ($p > 0.05$) at both slower and faster walking speed (fig. 2). Exercise heart rate (EHR) during conventional walking in the group I (5.5–6.5 km/h speed) and at both forms activity (W and NW) in the group II (7.5–8.5 km/h speed)

Table 1. Analysis of the biometric and physiological variables of female and male participants from Katowice (Group I) and Opole (Group II)

Variables	Female		Male	
	Group I – 5.5–6.5 km/h (n = 21)	Group II – 7.5–8.5 km/h (n = 32)	Group I – 5.5–6.5 km/h (n = 32)	Group II – 7.5–8.5 km/h (n = 33)
AG [years]	23.5 ± 0.9	22.4 ± 0.9***	23.4 ± 1.0	22.5 ± 0.8***
BH [cm]	165.5 ± 5.6	169.3 ± 5.0**	180.3 ± 6.3	180.4 ± 6.2
BM [kg]	59.7 ± 7.3	60.0 ± 6.7	78.4 ± 8.4	75.8 ± 8.6
BMI [kg/m^2]	21.7 ± 1.9	21.0 ± 2.6	24.1 ± 2.4	23.3 ± 2.2
RHR [bpm]	78 ± 12	80 ± 20	76 ± 10	81 ± 12

AG – age, BH – body height, BM – body mass, BMI – body mass index, RHR – reset heart rate. Significantly different form the Group I value: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

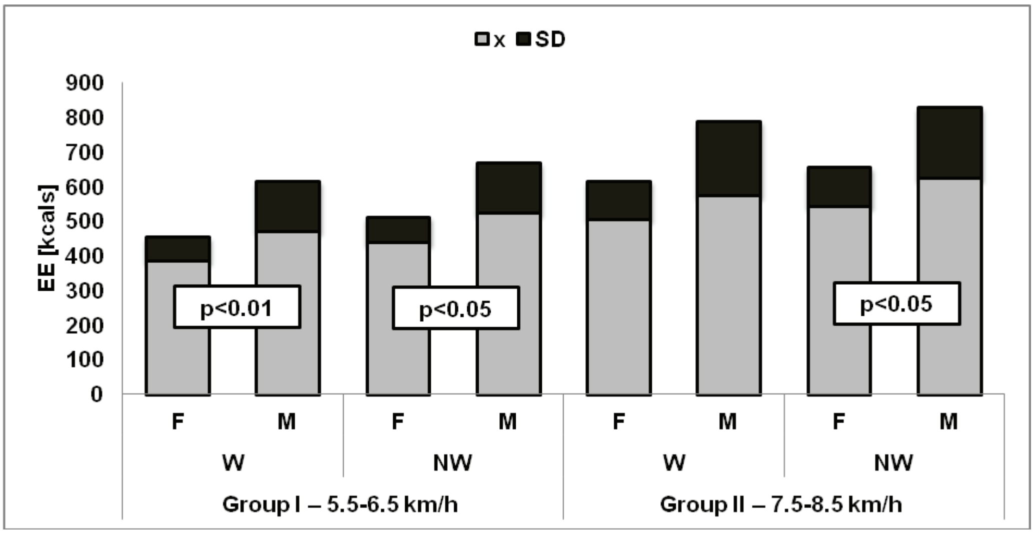

Fig. 1. Absolute energy expenditure (kcals) in groups of female (F) and male (M) during conventional walking (W) and Nordic walking (NW)

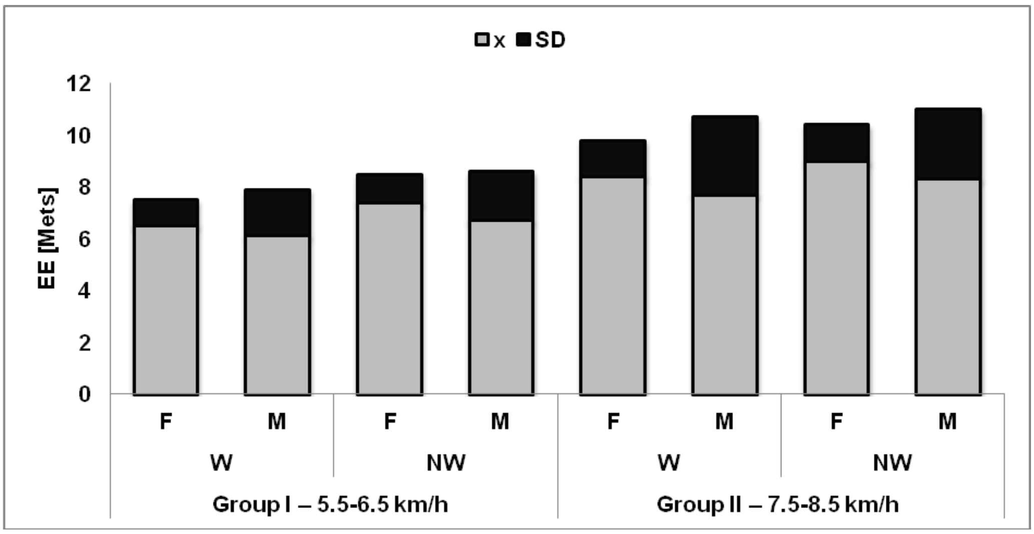

Fig. 2. Relative energy expenditure (METs) in groups of female (F) and male (M) during conventional walking (W) and Nordic walking (NW)

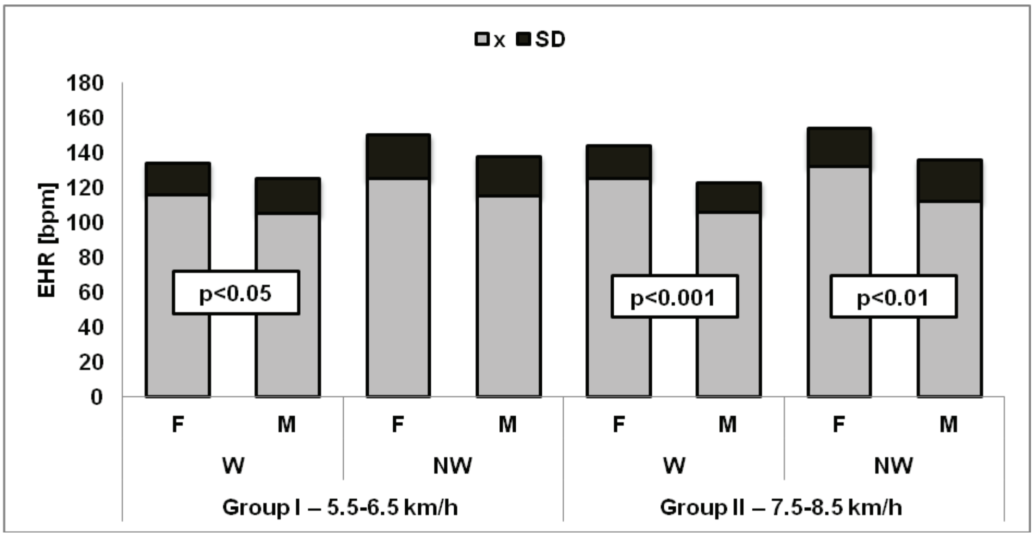

Fig. 3. Exercise heart rate (bpm) in groups of female (F) and male (M) during conventional walking (W) and Nordic walking (NW)

was significantly higher ($p < 0.05$) in women than in men (fig. 3).

Energy expenditure during Nordic walking (EE NW), expressed in kcals and METs, was both in women, and in men, at both analyzed speeds, significantly higher ($p < 0.01$) than during conventional walking (EE W) (tab. 2). Relative differences between the EE of NW and W, at the 5.5–6.5 km/h speed were 12.0–12.2% – in women, and 9.0–9.2% – in men. At the 7.5–8.5 km/h speed, these differences were 6.7–6.9% – in women, and 7.2–8.0% – in men, dependin g on the EE measurement units (METs or kcals).

Exercise heart rate (EHR) was higher ($p < 0.05$) during NW, compared to W, and the statistically significant differences were revealed in groups of women and men, regardless of their walking speed (table 2). Relative differences between the EHR values, during NW and W, at the 5.5–6.5 km/h speed were 7.2% – in women, and 8,7% – in men. At the 7.5–8.5 km/h speed, these differences were 5.3% – in women, and 5.4% – in men.

Discussion

In current study, we have assessed and compared the energy expenditure (EE) and exercise heart rate (EHR) of two walking conditions – Nordic Walking (NW) vs. conventional walking (W).

Our study data, reporting EE Nordic walking (EE NW) and during conventional walking (EE W) concur with the ones, presented in the updated version of compendium, estimating the caloric cost of various physical activity forms [1]. For instance, a caloric cost of NW, at about 8.0 km/h speed, has been estimated to be at a level

Table 2. The differences between energy expenditure (EE) and exercise heart rate (EHR) during conventional walking (W) and Nordic walking (NW)

Pair of variables	Female		Male	
	Group I – 5.5-6.5 km/h (n = 21)	Group II – 7.5–8.5 km/h (n = 32)	Group I – 5.5–6.5 km/h (n = 32)	Group II – 7.5–8.5 km/h (n = 33)
EE W – EE NW [kcals]	384.8 ± 68.2 437.3 ± 74.6***	506.2 ± 109.7 544.0 ± 110.9**	471.4 ± 143.3 523.0 ± 145.0***	573.8 ± 214.4 623.9 ± 204.1**
EE W – EE NW [METs]	6.5 ± 1.0 7.4 ± 1.1***	8.4 ± 1.4 9.0 ± 1.4**	6.1 ± 1.8 6.7 ± 1.9***	7.7 ± 3.0 8.3 ± 2.7***
EHR W – EHR NW [bpm]	116 ± 18 125 ± 25*	125 ± 19 132 ± 22*	105 ± 20 115 ± 23***	106 ± 17 112 ± 24

EE W – energy expenditure during conventional walking (without poles), EE NW – energy expenditure during Nordic Walking, HER W – exercise heart rate during conventional walking (without poles), HER NW – exercise heart rate during Nordic Walking. Significantly different form the conventional walking value: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

of 9.5 METs. In our study, it was 9.0 METs – in women and 8.3 METs – in men. In addition to some significant differences of the EE, related to both analyzed walking conditions (NW and W), we have found a statistically significant increase of the EHR during NW, compared to conventional walking.

This is in agreement with studies published by some other authors, using different measurement tools, according to which, a higher caloric cost and exercise heart rate (EHR) during NW, compared with conventional walking (without poles) were reported [3, 7, 11, 23, 27]. Similarly, based on the studies of NW and conventional walking on the track, Porcari and Hendrickson reported the increase of EE – by 22%, and the increase of EHR – by 16% during NW, compared to conventional walking [23]. Likewise, Church et al. have found in their studies the increase of EE – by almost 20% [kcal/min.], the increase of EHR – up to 4% in women, and up to 8% in men, during NW, compared to conventional walking [3]. These results differ from our study findings, in which, higher EE differences, during both NW and conventional walking have been reported.

Other studies investigating the EE and EHR, during NW and W, at 7,6 km/h speed, at a level surface (0%), and at a slope of 5%, and 10%, have confirmed an increased EE during NW (at different slope), compared to conventional walking [27]. The same was also revealed in studies by Hansen and Smith indicating that the EE during NW (uphill, downhill, and horizontal level) was significantly higher, compared to the one during conventional walking (without poles, at different slope). It has also been suggested that the caloric cost of NW might be different, depending on the poles' length [11].

In addition, some studies evaluating EE during NW and conventional walking, using varying pole weights, have confirmed the higher EE during NW, compared with conventional walking, indicating that the pole's weight does not contribute to the EE increase. Furthermore, this might only increase an activity of the arm's muscle [25]. Moreover, some previous studies of EE, during walking with trekking poles, at a different slope, have shown the significantly higher VO_2 and EHR, compared to walking without poles, under the same conditions. In contrast, the rating of perceived exertion (RPE) (scales 6–20 by Borg) remained unchanged [24]. There might also be some correlations between the EE and techniques of walking with poles. Studies by Figard-Fabers et al., investigating 11 middle-age obese women, have reported lower EE NW values, after practicing the NW technique (for four weeks, with frequency – three times per week, 45 min. per one session, with warm-up and cool-down), compared to those, recorded during the 'before NW training' period [7].

Using poles during walking increases the intensity of walking at a given speed, simultaneously increasing EE, without a substantially perceived exertion. This in turn, contributes to the increase of health benefits from physical exertion. In particular, it was found that the rating of perceived exertion, according to Borg's scale, among young women, during NW practice was substantially lower than the exercise intensity, assessed according to the oxygen consumption, and the heart rate frequency [13]. In addition, it has been emphasized that the significantly higher EE in NW may be caused by a specific, dynamic technique of NW, related to rebound with poles, during each step. That in turn, increases the body movements, registered by accelerometer, and in consequence, increases the length of steps during walking with poles, compared to conventional walking. Thus, at the same walking speed, to complete a given distance using NW technique would certainly require making a smaller number of steps, than during conventional walking. This has been confirmed by studies examining a range of motion of the foot (measured by goniometer at right heel) during NW, conventional walking and running. According to these studies, it was found that the maximum pronation takes place during NW [10]. An increased EE NW has also been caused by engagement of muscle of the upper body part, as a result of using poles [7, 24]. In studies by Hagen et al., a peak wrist acceleration during NW was measured. Peak wrist acceleration increases with walking speed. However, this type of wrist motion does not exist during conventional walking or running. Some concerns exist that repeated shaking of upper extremities might lead to trauma [10].

However, the above hypotheses need to be verified in further studies, using modern accelerometers, registering both kinesthetic parameters of performed movements and physiologic reactions of an organism to exertion.

Conclusions

Our study data have shown that during Nordic walking (NW), energy expenditure (EE) has been significantly higher than during conventional walking (without poles), regardless of a moving speed. EHR during NW has been significantly higher than during conventional walking that indicates a higher intensity of exertion during NW. Therefore, NW, despite a requirement of learning its movement technique, might present an attractive and cost effective form of physical recreation, resulting in health benefits that are essential in prevention of hypokinetic disorders.

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