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Original Article

Applicability of pedometry and accelerometry in the calculation of energy expenditure during walking and Nordic walking among women in relation to their exercise heart rate

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Abstract. [Purpose] The objective of this study was to evaluate the usefulness of pedometry and accelerometry in the measurement of the energy expenditures in Nordic walking and conventional walking as diagnostic parameters. [Subjects and Methods] The study included 20 female students (age, 24 ± 2.3 years). The study used three types of measuring devices, namely a heart rate monitor (Polar S610i), a Caltrac accelerometer, and a pedometer (Yamax SW-800). The walking pace at the level of 110 steps/min was determined by using a metronome. [Results] The students who walked with poles covered a distance of 1,000 m at a speed 36.3 sec faster and with 65.5 fewer steps than in conventional walking. Correlation analysis revealed a moderate interrelationship between the results obtained with a pedometer and those obtained with an accelerometer during Nordic walking ($r = 0.55$) and a high correlation during conventional walking ($r = 0.85$). [Conclusion] A pedometer and Caltrac accelerometer should not be used as alternative measurement instruments in the comparison of energy expenditure in Nordic walking.
Key words: Nordic walking, Accelerometer, Energy expenditure

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INTRODUCTION

Given its health benefits and natural movement technique, walking with poles (Nordic walking [NW]) has become an increasingly popular form of physical recreation[1, 2)]. Consequently, it has also increasingly become the subject of scientific research. NW is recommended especially for the elderly because poles are additional points of support and thus reduce the risk of falling[3, 4)].

Recent studies have shown that walking with poles can also be applied in the rehabilitation of patients with cardiovascular[5, 6)] and respiratory disorders[7)], Parkinson disease[8)], and metabolic disorders such as diabetes[9)] or obesity[10)]. Tschentscher et al. documented in their review numerous health benefits of NW in people of various ages[11)].

Scientific experiments compared between the energy expenditure (EE) in NW at different speeds and that in conventional walking (CW) at the same rate. For example, indirect calorimetry was used for this purpose, based on an analysis of the composition of respiratory gas[12, 13)]. Simpler techniques for the assessment of EE in locomotion movements have been used as methods of monitoring effort kinematic parameters, in which electronic or mechanical motion sensors record the number of steps (pedometry) or acceleration of the body in space (accelerometry).

The aim of this study was to evaluate the applicability of pedometry and accelerometry in the estimation of EEs in NW and CW in women, in relation to exercise heart rate (EHR) monitoring (pulsometry) during walking over a distance of 1,000 m.

SUBJECTS AND METHODS

The research was approved by the ethics committee of the Jerzy Kukuczka University of Physical Education in Katowice (NR 2/2012). The study included 20 female students in physiotherapy from the College of Strategic Planning in Dąbrowa Górnicza (mean ± SD: age, 24 ± 2.3 years; body height, 165.6 ± 6.9 cm; weight, 58.6 ± 11 kg; body mass index, 21.4 ± 3.3 kg/m^2). The tests were conducted in the spring, in the afternoon, on flat asphalt paths at the Pogoria III recreation center in Dąbrowa Górnicza. Before the measurements, the subjects were acquainted with the study purpose and procedure, and trained in advance to walk correctly with poles.

The study used three types of measuring devices, namely

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Table 1. Differences in various parameters between Nordic and conventional walking

	Nordic walking		Conventional walking		
Variables	x	SD	x	SD	d
Time (s)	642.5	60.3	678.8	63.1	−36.3*
Number of steps	1,257.9	86.7	1,323.4	73.5	−65.5*
Caltrac EE (kcal)	50.3	16.1	44.8	13.2	5.5*
Pedometer EE (kcal)	47.4	9.6	50.2	9.7	−2.8**
Exercise heart rate	128.5	19.0	117.1	17.2	11.4**

EE: energy expenditure
*p < 0.05, **p < 0.001

Table 2. Relationship between results obtained by using various devices during Nordic and conventional walking

	HR [bpm] (CW)	HR [bpm] (NW)	Pedometer EE [kcal] (CW)	Pedometer EE [kcal] (NW)	Caltrac EE [kcal] (CW)	Caltrac EE [kcal] (NW)
HR [bpm] (CW)	1.00					
HR [bpm] (NW)	0.86*	1.00				
Pedometer EE [kcal] (CW)	0.36	0.45*	1.00			
Pedometer EE [kcal] (NW)	0.44	0.51*	0.94*	1.00		
Caltrac EE [kcal] (CW)	0.49*	0.57*	0.85*	0.78*	1.00	
Caltrac EE [kcal] (NW)	0.46*	0.57*	0.64*	0.55*	0.60*	1.00

NW: Nordic walking, CW: conventional walking, HR: heart rate, EE: energy expenditure
*p < 0.05

a heart rate monitor (Polar S610i) to measure EHR and walking duration, a Caltrac accelerometer to assess EE, and a pedometer (Yamax SW-800) to record the number of steps and EE.

The students walked twice the distance of 1,000 m, walking separately at a pace of 110 steps/min. They were allowed a 3-hour resting break between the tests to normalize the heart rate to a rest state and to set up the second measurement and measuring devices. Walking pace (step frequency) was set for each person by using a metronome sound signal. The subjects started the trial at 1-minute intervals. The end result of both tests was expressed as the walking duration in seconds (s), recorded by using a heart rate monitor.

For the statistical analysis, the Statistica v. 10 software (StatSoft Inc., USA) was used. Arithmetic means (x), standard deviations (SD), and the differences between the mean values (d) were calculated. The Wilcoxon test was used to determine differences between measurements. Spearman rank correlation coefficients were calculated for results obtained from individual measuring devices.

RESULTS

Walking in a moderate pace using the NW technique was characterized by a significantly higher EHR and EE than CW, as measured by using the Caltrac accelerometer ($p < 0.05$). By contrast, CW showed higher EE than NW when measurements were made using a pedometer ($p < 0.001$). EHR was significantly higher during NW (128.5 bpm) than during CW (117.1 bpm; $p < 0.001$; Table 1).

Correlation analysis was performed to determine the correlation between HER and the estimates of EE measured with a pedometer and that measured with an accelerometer, both during CW and NW. EE measured with the Caltrac accelerometer and pedometer moderately correlated with EHR during NW (Table 2). The value of the correlation coefficient for the results obtained with an accelerometer and a pedometer was significantly higher during CW ($r = 0.85$) than during NW ($r = 0.55$). These results suggest the interchangeability of the two measuring devices when estimating EE in CW.

DISCUSSION

The study discusses the problem of assessing the suitability of pedometric and accelerometric techniques in estimating EE in walking forms of locomotion. The aim of the study was to assess the reliability of estimating the EE in CW and NW by using a pedometer and an accelerometer in relation to EHR monitoring results.

Subsequent analyses showed that the EE in NW, estimated by using an accelerometer, was approximately 5.5 kcal higher than in walking without poles. EE in CW was about 30 kcal more per hour. This phenomenon was confirmed by the higher EHR during NW, the value of which was moderately correlated with EE measured with an accelerometer.

The EE calculated from the number of steps (pedometer) was higher for CW, which clearly contradicts the lower EHR in this form of walking. The highly probable cause of this discrepancy is that a pedometer estimates the EE from the number of steps, which was higher in CW. Accelerometry is based on a more advanced technology and measures the acceleration that better characterizes intensity as a quality parameter of physical activity, as opposed to the number of steps, which is a quantitative parameter. In light of this argument, it should be concluded that an accelerometer is more useful for estimating EE in NW.

The higher EE in NW stems from the higher accelerations during body movements as recorded by the accelerometer, which is related to the dynamic muscle work of the shoulders, shoulder girdle, and back. This was confirmed by electromyographic studies[14, 15]. Consequently, exercising NW for a longer period of time results in increased muscle strength of the upper body[16], which is another advantage of NW over CW in terms of health benefits.

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