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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Oxygen uptake during Nordic walking training in patients rehabilitated after coronary events

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Abstract

Background: Nordic walking (NW) is an effective form of endurance training in cardiac rehabilitation (CR). The key parameter for the safety and effectiveness of the training is its intensity. Training intensity may be directly measured by the volume of oxygen consumption (VO_2), and indirectly by chronotropic cardiac response to exercise. No data have been published on the rates of VO_2 during NW in field conditions among patients rehabilitated after coronary events.

Aim: To assess the intensity of NW training in field conditions by measuring VO_2, energy expenditure (EE), and heart rate (HR) in comparison with a treadmill cardiopulmonary exercise test (CPET) in a group of patients rehabilitated after coronary events.

Methods: Thirteen men after percutaneous coronary intervention due to an acute coronary syndrome (STEMI, NSTEMI, or UA), aged 53.2 ± 8.2 years, were evaluated and recruited for comprehensive CR at 30.3 ± 15.7 days after the incident. Left ventricular ejection fraction was evaluated and treadmill exercise test (ExT) using an individualised ramp protocol was performed during initial functional assessment. Following risk stratification, patients began training at 50% of HR reserve (HRR). Participants at low and moderate risk qualified for field NW training in the second week of CR. Treadmill CPET using a ramp protocol was performed after the patients had mastered the technique of walking with poles. Next day, HR, parameters of ventilation, and respiratory gas concentrations were measured during NW using a portable spiroergometry system.

Results: Exercise tolerance estimated during initial ExT was 9.1 ± 2.5 MET. Peak VO_2 was 27.5 ± 5.4 mL/min/kg during CPET vs. 26.2 ± 7.7 mL/min/kg during NW ($p < 0.447$). Mean VO_2 during NW was 17.5 ± 4.5 mL/min/kg, which amounted to 59.4 ± 18.6% of VO_2 reserve in CPET. Mean HR during NW was 104.8 ± 9.8 bpm, amounting to 63.7 ± 28.7% of HRR, and peak HR was 128.4 ± 13.7 bpm vs. 131.1 ± 18.0 bpm during CPET ($p < 0.628$). EE during 24.7 ± 9.7 min of NW was 210.7 ± 149.0 kcal (8.1 ± 2.7 kcal/min).

Conclusions: The intensity of NW training in field conditions in patients after coronary events was 59% of VO_2 reserve, and its peak instantaneous intensity reached values obtained during CPET on a treadmill. EE during NW in the study group was 8.1 kcal/min. Chronotropic response during NW was 64% of HRR, and its instantaneous increase reached the maximum HR obtained during CPET.

Key words: cardiac rehabilitation, Nordic walking, oxygen uptake

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INTRODUCTION

Nordic walking (NW), which involves large muscle groups, has become an effective form of endurance training in cardiac rehabilitation (CR) after acute coronary events [1, 2], in patients with moderate and severe heart failure [3], in the elderly [4, 5], and in patients with risk factors for coronary artery disease [6, 7]. When planning training during rehabilitation, the key parameter for the safety and effectiveness of the training is its intensity. Training intensity may be directly measured by the volume of oxygen consumption (VO_2), and indirectly by chronotropic cardiac response to exercise. Total exercise VO_2 allows indirect calculation of energy expenditure (EE) which is cardioprotective at the level of 1500 kcal per week [8]. In comparative studies of walking and NW in young healthy subjects on a treadmill [9, 10] and in field conditions at a distance of 200 m [11], and in patients with ischaemic

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heart disease on a treadmill [1], VO_2 during NW was higher by 12–23%. No data have been published on the rate of VO_2 during NW in various field conditions among patients rehabilitated after coronary events.

The aim of the study was to assess the intensity of NW training in field conditions by measuring VO_2, EE, and heart rate (HR) in comparison with a treadmill cardiopulmonary exercise test (CPET) in a group of patients undergoing comprehensive CR after coronary events.

METHODS

We analysed data from our centre database of routine examinations in patients undergoing phase II comprehensive CR [12]. We included patients after a percutaneous coronary intervention performed for the treatment of ST segment elevation myocardial infarction, non-ST segment elevation myocardial infarction or unstable angina, with left ventricular ejection fraction (LVEF) > 40% and exercise tolerance > 5 metabolic equivalents (MET; 1 MET = 3.5 mL/min/kg VO_2). We excluded patients who underwent cardiac surgery, patients with musculoskeletal system dysfunction, overt heart failure, arrhythmias or conduction disturbances, or severe myocardial ischaemia during exercise test (ExT), and without haemodynamically significant valvular heart disease. Characteristics of the study group are shown in Table 1.

Initial functional evaluation included echocardiography (VIVID 4 GE) with LVEF measurements and treadmill electrocardiographic ExT (CASE 6.0 GE Medical Systems) using a ramp protocol [13]. Depending on exercise tolerance evaluated using the Duke Activity Status Index (DASI) [14], one of the three individualised ramp protocols was chosen (Ramp5, Ramp7, and Ramp10 Rybicki with the workload of 5, 7, or 10 MET at 10 min, respectively, to allow the desired duration of exercise of 10 ± 2 min). Workload parameters during ExT are shown in Table 2, with treadmill MET values estimated using the American College of Sports Medicine formula [15].

For rehabilitation purposes, ExT was limited by severe exertion (Rating of Perceived Exertion [RPE] of 15–16) [16, 17] or development of absolute or relative indications for termination of the test [18].

Based on these examinations and an analysis of medical records pertaining to the acute event, cardiac event risk category was evaluated [12] and training HR (trHR) at the level of 50% of HR reserve (50% HRR) was calculated using the following formula: trHR = Int × (pHR – rHR) + rHR [19], where Int is training intensity expressed as a fraction (0.5), pHR is peak HR during Ext, and rHR is resting HR.

Study patients were subjected to a full program of comprehensive CR that included kinesiotherapy, drug therapy, psychotherapy health education, and treatment of concomitant diseases and modifiable risk factors. Training program was initiated under model C, including cycloergometer or treadmill training at the intensity of 40–50% HRR. After 5 days, in low or moderate risk patients who tolerated the exercise well, the training was intensified to model B and then model A at 60–70% HRR [12]. In models B and A, NW in field conditions was introduced alternatively with water-based exercise, depending on the weather conditions.

Table 1. Characteristics of the study group

Parameter	Value
Number of patients and gender	13 men
Age [years]	53.2 ± 8.2
Body mass [kg]	87.5 ± 13.0
Height [cm]	175.8 ± 8.8
Body mass index [kg/m²]	28.2 ± 2.3
Time from ACS to admission [days]	30.3 ± 15.7
Diagnosis	PCI: n = 13, STEMI: n = 8, NSTEMI: n = 3, UA: n = 2
Stent implantation to LAD/RCA/CX/OM1	n = 5/n = 7/ /n = 3/n = 3
Concomitant conditions:	
Hypertension	n = 11
Diabetes type 2	n = 3
Total cholesterol/LDL-C/HDL-C [mmol/L]	5.72 ± 1.74/4.28 ± ± 1.34/1.24 ± 0.18
Smoking before ACS	n = 9
Markers of myocardial necrosis during ACS:	
Troponin [µg/L]	2.66 ± 2.17
Creatinine kinase-MB [µg/L]	47.76 ± 29.06

ACS — acute coronary syndrome; PCI — percutaneous coronary intervention; STEMI — ST elevation myocardial infarction; NSTEMI — non-ST elevation myocardial infarction; LAD — left anterior descending artery; RCA — right coronary artery; CX — left circumflex artery; OM1 — first obtuse marginal branch; LDL-C — low-density lipoprotein cholesterol; HDL-C — high-density lipoprotein cholesterol

When the patients mastered the technique of NW, treadmill CPET was performed using the same procedure as ExT, and ventilation and gas exchange parameters were recorded on the next day during NW. For both examinations, a portable spiroergometry system (START 2000 – MES) was used. Examinations were performed in accordance to the current guidelines [20] after volume and gas calibration before each testing.

Recorded parameters were averaged in 30 s intervals. VO_2 was expressed as relative values per kilogram of body mass in mL/min/kg.

Nordic walking was performed at the level of health training by certified instructors using a predetermined route of 1030 m with height difference of 16 m. The route include a 363-m long 4.5% elevation and two downslopes, one 120 m long at 8.4% and the other 136 m long s at 6%. During the training, HR was monitored using a pulse meter (Polar FS1) with the alarm set individually at 70% HRR. A NW session was initiated

Table 2. Parameters of exercise tests using ramp protocols

Protocol:		Ramp5 Rybicki			Ramp7 Rybicki			Ramp10 Rybicki		
Stage	Duration [min:s]	Velocity [km/h]	Inclination [%]	MET	Velocity [km/h]	Inclination [%]	MET	Velocity [km/h]	Inclination [%]	MET
1	Start	1.5	0	1.7	1.7	0	1.8	1.8	0	1.9
2	01:00	1.5	0	1.7	1.7	0	1.8	1.8	0	1.9
3	04:00	2.2	2.5	2.5	2.6	3.5	3.0	3.2	4.0	3.6
4	07:00	2.8	5.0	3.6	3.5	7.0	4.8	4.6	8.0	6.3
5	10:00	3.6	7.5	5.0	4.4	10.5	7.0	6.0	12.0	10.0
6	13:00	4.3	10.0	6.7	5.3	14.0	9.9	7.4	16.0	14.7
7	16:00	5.0	12.5	8.7	6.2	17.5	13.2	8.8	18.0	20.3

MET — metabolic equivalent [1 MET = 3.5 mL/min/kg]

with warm-up stretching and respiratory exercises for 5 min. During the endurance training phase, NW was performed for 30 min at 12–14 RPE and HR $\leq$ 70% HRR. Training session was concluded with a cool-down, slow walk with poles for 10 min.

Exercise intensity during NW was evaluated based on instantaneous parameters averaged in 30 s intervals, HR (Int_HR) and VO_2 (Int_VO_2), according to the formulas: Int_HR [%] = = 100 × (HR – rHR) / (pHR – rHR), where HR is instantaneous HR during NW, pHR is peak HR during CPET, and rHR is resting HR during CPET; Int_VO_2 [%] = 100 × (VO_2 – 3.5) / (pVO_2 – 3.5), where VO_2 is instantaneous VO_2 during NW, pVO_2 is peak VO_2 during CPET, and 3.5 is the resting VO_2 of 3.5 mL/kg/min.

Total EE was calculated using the formula: EE [kcal] = = VO_2 × BM × t / 200, where BM is body mass in kilograms, and t is duration of exercise in minutes [21].

Statistical analysis

Mean parameters obtained during CPET and NW training were compared using the 2-sided Student *t* test for paired samples. Calculations were performed using the SPSS Statistics 20 (IBM) statistical package. Data were expressed as mean values ± standard deviation (SD).

RESULTS

Results of echocardiographic measurements are shown in Table 3.

Exercise tolerance estimated during initial ExT was 9.1 ± 2.5 MET. During exercise continued to 15–16 RPE, rHR increased from 68.9 ± 10.0 bpm to 124.7 ± 21.5 bpm. Calculated trHR at 50% HRR was 96.8 ± 14.3 bpm. Eight (61.5%) patients were categorised as having low risk of exercise-induced cardiac events, and the remaining 5 (38.5%) patients were categorised as having moderate risk. Spiroergometric data obtained during CPET and NW training are summarised in Table 4.

Relative VO_2 values during CPET and NW training are shown in Figure 1.

Table 3. Cardiac echocardiographic parameters

Parameter	Value
LVEDD [cm]	4.98 ± 0.50
LVESD [cm]	3.50 ± 0.34
LVEDV [mL]	118.9 ± 27.7
LVESV [mL]	56.2 ± 12.4
IVSd [cm]	1.13 ± 0.16
IVSs [cm]	1.65 ± 0.17
PWd [cm]	1.05 ± 0.21
PWs [cm]	1.56 ± 0.25
LVEF [%]	52.0 ± 5.0
Right ventricular dimension [cm]	2.77 ± 0.30
Aortic diameter [cm]	3.42 ± 0.31
Left atrial dimension [cm]	3.87 ± 0.26
Mitral valve	R: n = 9 (+)
Aortic valve	R: n = 4 (+)
Tricuspid valve	R: n = 6 (+)
Pulmonary valve	–

LVEDD — left ventricular end-diastolic dimension; LVESD — left ventricular end-systolic dimension; LVEDV — left ventricular end-diastolic volume; LVESV — left ventricular end-systolic volume; IVSd — interventricular septum thickness at diastole; IVSs — interventricular septum thickness at systole; PWd — posterior wall thickness at diastole; PWs — posterior wall thickness at systole; LVEF — left ventricular ejection fraction; R — regurgitation

Peak VO_2 during NW training was 95.7 ± 21.7% of pVO_2 during CPET, a non-significant difference ($p < 0.449$), and mean VO_2 during training was 59.4 ± 18.6% of VO_2 reserve during CPET. In 4 patients (31% of study subjects) observed pVO_2 during training was higher than during CPET, with moderate perceived exertion (Fig. 2).

Chronotropic response during CPET and NW training are shown in Figure 3.

Table 4. Spiroergometric data during cardiopulmonary exercise test (CPET) and Nordic walking

Parameter	CPET	Nordic walking	
		Peak value	Mean value
rSBP [mm Hg]	121.5 ± 9.0	118.1 ± 8.1	
rDBP [mm Hg]	78.5 ± 5.5	72.3 ± 6.0	
VO_2 [L/min]	2.43 ± 0.90	2.30 ± 1.01	1.54 ± 0.49
VCO_2 [L/min]	2.54 ± 0.94	2.24 ± 1.03	1.35 ± 0.43
Respiratory exchange ratio	1.05 ± 0.07	0.97 ± 0.06	0.88 ± 0.04
Metabolic equivalent	7.85 ± 1.56	7.49 ± 2.22	4.99 ± 1.28
VO_2/HR [mL]	18.64 ± 4.66	19.05 ± 8.02	14.04 ± 4.71
Minute ventilation [L/min]	62.5 ± 20.2	58.6 ± 16.0	38.7 ± 11.5
Breathing frequency [1/min]	32.6 ± 8.9	34.9 ± 5.1	26.8 ± 4.1
VE/VO_2	39.3 ± 9.1	42.9 ± 7.6	35.8 ± 6.7
VE/CO_2	27.2 ± 2.8	33.3 ± 7.4	27.2 ± 5.0
pSBP [mm Hg]	156.9 ± 17.0	133.5 ± 10.9*	
pDBP [mm Hg]	85.4 ± 5.2	81.1 ± 3.0*	

*Measurements immediately after training; SBP — systolic blood pressure; DBP — diastolic blood pressure; VO_2 — volume of oxygen consumption; VCO_2 — volume of carbon dioxide exhaled; VO_2/HR — oxygen pulse; VE/VO_2 — ventilation equivalent for oxygen; VE/VCO_2 — ventilation equivalent for carbon dioxide; p — peak; r — resting

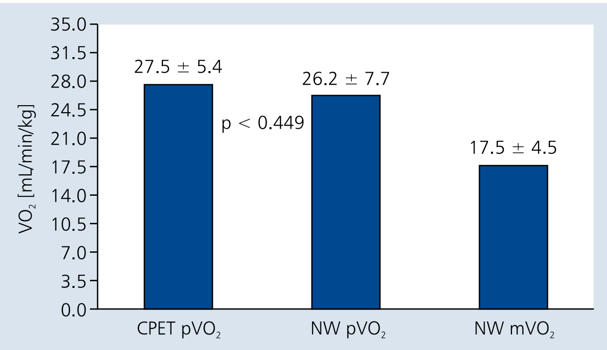

Figure 1. Relative volume of oxygen consumption (VO_2) values during cardiopulmonary exercise test (CPET) and Nordic walking (NW). CPET pVO_2 — peak VO_2 during CPET; NW pVO_2 — peak VO_2 during NW; NW mVO_2 — mean VO_2 during NW

Peak HR during CPET and NW training did not differ significantly ($p < 0.628$). Mean training intensity was 63.7 ± 28.7% of HRR during CPET, with perceived exertion of not more than 13 RPE.

Mean total EE during 24.7 ± 9.7 min of NW was 210.7 ± 149.0 kcal (881.2 ± 623.4 kJ), which corresponds to 8.10 ± 2.68 kcal per 1 min of walking with poles.

DISCUSSION

In the study group, NW training went uncomplicated, and this form of field activity was readily undertaken by the patients. Mean and peak VO_2 observed during the training indicate that its intensity may be categorised as moderate to severe [22]. Due to intensity of NW, patients after coronary events should be carefully selected for this form of training, and HR monitoring should be used throughout the training to avoid longer lasting trHR increases above the target value. Higher VO_2 values observed in 4 patients during NW than during CPET may be explained by recruitment of a larger muscle mass during NW compared to walking on a treadmill without the use of poles. Evaluation of VO_2 during NW in field conditions in patients with coronary artery disease has not been reported in the literature. Rodgers et al. [9] evaluated VO_2 and EE in young women during 30 min of NW and walking flat on a treadmill at 6.7 km/h. Mean VO_2 was 20.5 mL/min/kg during NW compared to 18.3 mL/min/kg during walking on a treadmill. Total EE was 173.7 and 140.7 kcal, respectively, with similar perceived exertion. Similarly, in a group of 32 young men and women Porcari et al. [10] found that VO_2 during NW was 23% higher compared to walking on a treadmill at 1.7 m/s (24.0 vs. 19.6 mL/min/kg, respectively). In coronary artery disease patients undergoing rehabilitation, the same authors [1] found VO_2 to be 21% higher during walking on a treadmill using poles (1.60 ± 0.18 L/min) compared to walking without poles (1.30 ± 0.18 L/min), with the former activity also associated with a higher chronotropic response (a HR difference of 14 bpm). In a study of 11 young women and 11 men, VO_2 was 14.9 mL/min/kg during flat walking and 17.9 mL/min/kg during NW in women, and 12.8 mL/min/kg and 15.5 mL/min/kg, respectively, in men [11]. Thus, VO_2 values during NW measured in our study are comparable to the published data in healthy subjects and patients with ischaemic heart disease evaluated on a treadmill.

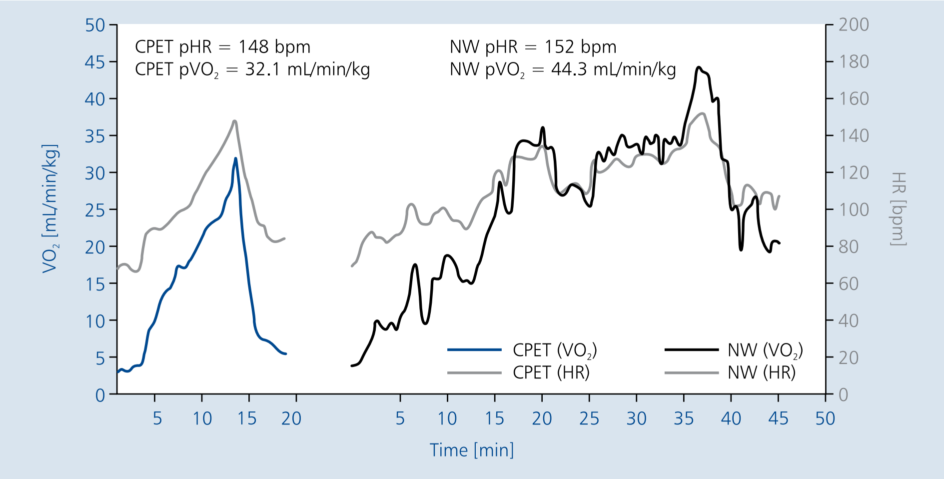

Figure 2. Example of volume of oxygen consumption (VO_2) and heart rate (HR) recording during cardiopulmonary exercise test (CPET) and Nordic walking (NW); CPET pHR — peak HR during CPET; CPET pVO_2 — peak VO_2 during CPET; NW pHR — peak HR during NW; NW pVO_2 — peak VO_2 during NW

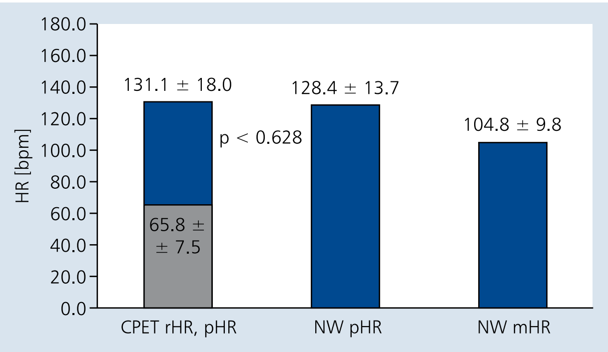

Figure 3. Heart rate (HR) values during cardiopulmonary exercise test (CPET) and Nordic walking (NW); CPET rHR/pHR — resting/peak HR during CPET; NW pHR — peak HR during NW; NW mHR — mean HR during NW

Tschentscher et al. [23] reviewed 16 randomised controlled trials and 11 observational studies, selected for analysis from the overall of 211 reports on NW published until May 2012. In randomised controlled trials examining effects of NW in various chronic condition, the total number of patients was 559 in the active treatment groups and 503 in the control groups. In observational studies, short-term effects of NW were evaluated in 831 subjects. The authors concluded that NW had a beneficial effect on resting HR, blood pressure, exercise capacity, VO_2, and quality of life in patients with various conditions. Thus, it can be widely recommended in both primary and secondary prevention.

Limitations of the study

One methodological limitation of the study was a low number of patients.

CONCLUSIONS

The intensity of NW training in field conditions in patients after coronary events was 59% of VO_2 reserve, and its peak instantaneous intensity reached values obtained during CPET on a treadmill. EE during NW in the study group was 8.1 kcal/min. Chronotropic response during NW was 64% of HRR, and its instantaneous increase reached the maximum HR obtained during CPET.

Conflict of interest: *none declared*

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Wielkość pochłaniania tlenu w czasie treningu *Nordic walking* u chorych rehabilitowanych po incydentach wieńcowych

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Streszczenie

Wstęp: *Nordic walking* (NW) jest efektywną formą treningu wytrzymałościowego w rehabilitacji kardiologicznej (CR). Kluczowym parametrem dla bezpieczeństwa i efektywności treningu jest jego intensywność. Bezpośrednią jej miarę stanowi wielkość pochłaniania tlenu (VO_2), a pośrednią — odpowiedź chronotropowa serca na wysiłek. Dane na temat wielkości VO_2 w czasie treningu NW w terenie u chorych rehabilitowanych po incydentach wieńcowych nie były dotychczas publikowane.

Cel: Celem pracy była ocena intensywności treningu NW w terenie za pomocą pomiaru VO_2 i wydatku energetycznego oraz częstotliwości rytmu serca (HR) w porównaniu z wynikiem testu spiroergometrycznego (CPET) na bieżni mechanicznej u rehabilitowanych chorych po incydentach wieńcowych.

Metody: Przebadano 13 mężczyzn w wieku 53,2 ± 8,2 roku po przezskórnej interwencji wieńcowej w przebiegu zawału serca (STEMI: 8 osób, NSTEMI: 3 osoby) i niestabilnej dławicy (2 pacjentów), włączonych do kompleksowej CR po 30,3 ± 15,7 dnia od incydentu. We wstępnej ocenie czynnościowej oznaczono echograficznie frakcję wyrzutową lewej komory i wykonano submaksymalny elektrokardiograficzny test wysiłkowy (ExT) na bieżni mechanicznej wg zindywidualizowanego protokołu ramp. Po stratyfikacji ryzyka zdarzeń sercowych chorzy rozpoczęli trening z intensywnością 50% rezerwy HR (50% HRR). W drugim tygodniu usprawniania pacjentów z niskim i umiarkowanym ryzykiem kwalifikowano do treningu NW w terenie. Po opanowaniu przez nich techniki marszu z kijkami wykonywano CPET na bieżni ruchomej wg protokołu ramp. Kolejnego dnia przeprowadzano rejestrację HR oraz parametrów wentylacyjnych i stężeń gazów oddechowych w trakcie treningu NW za pomocą przenośnego systemu do spiroergometrii.

Wyniki: Estymowana wydolność chorych we wstępnym ExT wynosiła 9,1 ± 2,5 MET. Szczytowe VO_2 (pVO_2) w CPET na bieżni wynosiło 27,5 ± 5,4 vs. 26,2 ± 7,7 ml/min/kg zarejestrowane podczas NW ($p < 0,447$). Średnie VO_2 (mVO_2) w czasie NW wynosiło 17,5 ± 4,5 ml/min/kg, co odpowiadało intensywności wysiłku równej 59,4 ± 18,6% rezerwy VO_2 (VO_2R) uzyskanej w CPET. Średnia HR (mHR) w czasie NW 104,8 ± 9,8 bpm stanowiła 63,7 ± 28,7% HRR, przy wartości pHR równej 128,4 ± 13,7 vs. 131,1 ± 18,0 bpm w CPET ($p < 0,628$). Wydatek energii w trakcie 24,7 ± 9,7-minutowego NW wynosił 210,7 ± 149,0 kcal, co w przeliczeniu na 1 min marszu stanowiło 8,1 ± 2,7 kcal/min.

Wnioski: Intensywność treningu NW prowadzonego w terenie u chorych po incydentach wieńcowych wynosiła 59% rezerwy VO_2, a jego wzrost chwilowy osiągał wartość szczytową uzyskaną w CPET na bieżni mechanicznej. Wydatkowana energia w czasie NW w badanej grupie chorych wynosiła 8,1 kcal w ciągu 1 min marszu z kijkami. Odpowiedź chronotropowa w NW utrzymywała się na poziomie 64% rezerwy tętna, a jej chwilowy wzrost osiągał maksymalną częstość uzyskaną w czasie testu spiroergometrycznego.

Słowa kluczowe: rehabilitacja kardiologiczna, *Nordic walking*, pochłanianie tlenu

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