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ORIGINAL ARTICLE

Effects of Nordic walking on cardiovascular performance and quality of life in coronary artery disease

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ABSTRACT

BACKGROUND: Cardiometabolic effects of physical exercise depend on its intensity, duration, and type. Conventional cardiovascular rehabilitation (CCVR) programs have significant advantages, but non-conventional activities such as Nordic walking (NW) may offer additional health benefits.
AIM: The aim of this study was to determine the feasibility and effectiveness of NW on cardiovascular performance and quality of life in patients with coronary artery disease (CAD) compared to a CCVR program.
DESIGN: This was a pseudo-randomized, prospective, single-blinded, parallel-group trial.
SETTING: The study was conducted at a resort/spa type facility located in a mountainous natural environment, 650 meters above sea level.
POPULATION: Eighty-three CAD patients were allocated to either a Nordic walking or a control group.
METHODS: The NW group (N.=53; age 59.1±7.0 years) underwent a three-week outdoor exercise program consisting of 40 minutes of walking four-times per week, whereas the controls performed traditional walking instead of NW. A patient's prescribed exercise intensity was according to exertion tolerance within 50-70% of peak oxygen consumption (VO_{2max}); rating of perceived exertion 'mild/moderate' (12 to 14 points) on the 0-20 Borg Scale. Primary endpoint: cardiovascular and functional performance (exercise ergometry [EE], metabolic equivalent of tasks [METs], ejection fraction [EF], Six-Minute Walking Test [6MWT]). Secondary endpoint was quality of life (Short-Form 36 Health Survey). Statistical analysis was performed by generalized estimating equations with Cohen's *d* effect size (ES).
RESULTS: NW led to higher cardiovascular performance compared to CCVR (ΔEE: +11.0% *vs.* +3.2%, small ES; ΔMETs: +9.8% *vs.* +1.5%, medium ES) and better functional performance (Δ6MWT: +8.3% *vs.* +5.1%, small ES). No significant differences were detected in EF (P=0.240) and SF-36 (PCS, P=0.425; MCS, P=0.400).
CONCLUSIONS: A three-week NW training program had clinically important effects, above and beyond CCVR, on cardiovascular and functional performance in CAD patients.
CLINICAL REHABILITATION IMPACT: Nordic walking is an accessible, safe, and effective low-threshold cardiac rehabilitation exercise training modality that seems to be particularly well-suited for people with limited functional and motivational capacities.

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KEY WORDS: Walking; Cardiac rehabilitation; Cardiovascular diseases; Coronary artery disease.

Coronary artery disease (CAD), as one of the two major forms of cardiovascular diseases, is the single most common cause of death and disability adjusted life years (DALYs) worldwide.[1, 2] Regular physical exercise is a cornerstone in the prevention and treatment of cardiovascular disease, as it leads to reductions in cardiovascular mortality and hospitalizations and improves the risk profile, exercise capacity, muscle strength, and endurance as well as quality of life across age groups.[3, 4] The European Guidelines on Cardiovascular Disease Prevention in Clinical Practice recommend at least 150 minutes a week of moderate aerobic physical activity (30 minutes for 5 days/week) or 75 minutes a week of vigorous physical activity (15 minutes for 5 days/week) or a combination thereof.[5] Despite these recommendations, sedentary behavior is on the rise and is contributing to an increase in cardiovascular morbidity

and mortality,[2, 6] thus justifying the growing attention towards exercise-based cardiac rehabilitation programs for secondary prevention.[7] The drawback is that the efficacy of exercise-based programs relies heavily on patient adherence,[5, 8] which leads to a search for a wide range of methods that attempt to increase patient participation and compliance by being both physically and psychologically engaging and easily accessible. Applying the principles of Behavior Change Wheel[9] we searched for methods that are targeting both conscious and non-conscious[10] processes and can be utilized at individual as well as population level. Nordic walking (NW) is one such activity.

Nordic walking (or outdoor pole walking) is a particular form of physical activity, where regular, natural walking is enhanced by the addition of the active use of pair of specially-designed Nordic walking poles, as stated by the International Nordic Walking Federation (INWA; www.inwa-nordicwalking.com). The result is a full-body workout that combines the ease and accessibility of conventional walking with upper body conditioning. The additional engagement of the upper body, resulting in the involvement of approximately 70-90% of the body's skeletal musculature and relatively higher energy expenditure by an estimated 8% compared with traditional walking, makes NW an interesting complementary tool to conventional cardiovascular rehabilitation (CCVR) program.[11]

Previous studies have shown that NW enhances aerobic capacity, muscular strength, balance, and overall well-being in healthy subjects[12] as well as in elderly.[13, 14] NW has also been shown to exert beneficial effects on several relevant parameters, such as resting heart rate, blood pressure, exercise capacity, maximal oxygen consumption, and quality of life in patients with a chronic disease;[12] including chronic obstructive pulmonary disease,[15] Parkinson's disease,[16, 17] obesity,[18] diabetes,[19] fibromyalgia,[20] breast cancer,[21] neck/shoulder pain,[22] major depression,[23] and selected cardiovascular diseases.[24]

Yet, a recent systematic review and meta-analytic article examining the efficacy of NW as compared to CCVR programs identified only two randomized controlled trials in patients with coronary artery disease.[24] Studies by Wilk *et al*. and by Kocur *et al*. compared a combined NW+CCVR program with a CCVR program alone, and both studies yielded improvements in exercise capacity in terms of metabolic equivalents (METs) and in several components of the Fullerton Functional Fitness Test, which were found to be superior following NW+CCVR.[25, 26] No significant differences were detected between NW+CCVR and CCVR in functional mobility (Six-Minute Walking Test, 6MWT), strength assessments, and flexibility of the upper and lower parts of the body. Nevertheless, as Cugusi *et al.* pointed out, these previous studies were of low to moderate quality yielding several methodological flaws, such as a relatively small sample size, gender imbalance, and univariate analyses. However, the most significant limitation was that NW was administered in combination with CCVR programs, possibly resulting in an additive effect due to the increased workout volume instead of NW effect itself.[24]

In view of the above-mentioned, the focus of our study was to examine the specific role played by NW rather than the increased volume of exercise due to simply adding NW to a CCVR program. In particular, the aim of this study was to examine the health effects and clinical relevance of a three-week NW training as compared to CCVR training of same intensity and duration and to determine a precise estimate of NW-induced changes on the primary outcome (cardiovascular and functional performance) and on the secondary outcome (quality of life) in individuals diagnosed with CAD. We hypothesized that CAD patients performing NW training for three weeks will show higher improvements in cardiovascular and functional performance as compared to patients in a CCVR training due to additional engagement of the upper body resulting in higher oxygen consumption and higher energy expenditure.

Materials and methods

Design

The present study was designed as a prospective, pseudo-randomized controlled trial. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, P.J. Safarik University in Kosice (approval no. 14/2013), and all patients gave written informed consent before participating in the study. Prior to the study, the effect size and variances were estimated by choosing an effect size of 0.25 (Cohen's f), which was judged to allow detection of relevant between-group differences in ANOVA with repeated measurements. The sample size of our study was determined using G*Power.[27] Under an alpha level of 0.05, a required minimum sample size of 54 was identified as necessary to obtain a statistical power of 0.80.

Participants and setting

The study was conducted at a resort/spa type facility — the Cardiovascular Rehabilitation Center in Vysne Ruzbachy — located in a mountainous natural environment, 650 meters above sea level. Participants were recruited from

new referrals to the Institute's cardiac rehabilitation program over a period of 6 months (from April to September). Inclusion criteria were: CAD patients irrespective of sex or age who had undergone revascularization — coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI), had a New York Heart Association (NYHA) class I-III, and stable CAD on optimal medical therapy. Exclusion criteria were: patients with unstable coronary syndromes, decompensated heart failure (NYHA IV), uncontrolled arrhythmias, unstable angina, chronic inflammatory disease, malignancy, severe liver or kidney insufficiency, orthopedic spinal and hip-joint problems.

Procedure

Recruitment and baseline assessment

Physiotherapists from the cardiac rehabilitation program approached potential participants about study participation during program intake sessions. Interested individuals were directed to a study coordinator, who pre-screened patients for eligibility and obtained informed consent. Baseline data concerning demographics, ejection fraction, revascularization method, and cardiovascular history were extracted from the patient's medical record. Functional status was assessed by a cardiologist based on the NYHA classifications according to the New York Heart Association classification of dyspnea symptoms.[28] Anthropometric measurements (body weight, waist circumference) were determined applying the WHO methodology.[29] Resting heart rate and blood pressure were measured using OMRON M7 Intelli IT digital tonometers (OMRON, Kyoto, Japan). Baseline exercise tolerance assessment, including determining the values of the submaximal and maximal heart rates, was performed using a stationary cycle ergometer (ERGOLINE, Ergoselect 200P, Bitz, Germany). METs (metabolic equivalent of tasks) capacity and maximal oxygen consumption (VO_{2max}) were also calculated from the symptom-limited bicycle test. The 2D echocardiography was used to determine ejection fraction (EF) by the planimetric method (Philips HD7XE, Eindhoven, the Netherlands). A standard 6MWT was then conducted.[30] Finally, patients completed the SF-36 quality of life questionnaire.[31]

Subject allocation and blinding

Following baseline assessment, participants were assigned to study conditions by the center physicians in 2:1 ratio using an alternating sequence wherein every other individual enrolled (1, 2, 4, 5, etc.) was assigned to the NW program and the alternate subjects enrolled (3, 6, 9, etc.) were assigned to the CCVR program. The research coordinator notified participants of their treatment assignment immediately. This was a single-blinded study, although cardiopulmonary stress tests were conducted by technical staff blind to treatment allocation. Those who participated in the data collection did not participate in the statistical processing of the questionnaires and the interpretation of the study results.

Intervention

The complete 3-week intervention program consisted of aerobic training with a total duration of 220 minutes a week. The weekly aerobic training included stationary bicycle exercise and hydrokinesiotherapy (aerobic exercises in a swimming pool) — each with a duration of 30 minutes once a week. This was complemented with a walking session (with or without poles) four times a week. The submaximal walking session lasted 40 minutes in total, 5 minutes of which was a warm-up phase (respiratory exercises), 30 minutes was the main aerobic phase, and each session closed with a 5-minute recovery phase (stretching exercises). The walking training exercise was performed outdoors. The rugged 1750-metre long hiking trail with 100 meters of incline was located within the perimeter of the Cardiovascular Rehabilitation Centre. Participants exercised in groups (5-10 patients in one group) under direct supervision of a certified physiotherapist. Patients performed maximal exercise testing to obtain maximum heart rate (HR). The pre-set goal for training efficiency was set at 75% of the initial maximum HR. Blood pressure and heart-rate parameters before and after each training session were recorded by a therapist. In addition, during the training heart rate was measured by smart watch heart rate monitor (POLAR model M430, Kempele, Finland) and individual workload was assessed using the Borg scale.[32] A patient's prescribed exercise intensity was according to exertion tolerance within 50-70% of VO_{2max}. Symptoms of angina and shortness of breath were also recorded.[33]

The NW group

Patients in the NW group received one hour of instruction from a certified NW instructor to assure proper pole use according to recommendations from the International Nordic Walking Association.[34] Participants used LEKI walking poles weighing approximately 450 grams each. The body of the poles are made to be adjustable to the height of the user. The soft tip of the pole is made of 100% rubber and is designed to be shock absorbent, and slip resistant. The handles are anatomically designed to fit the hand and were adjusted according to each patient's comfort and

hand anatomy. The workload for each participant was individualized based on information from enrolment exercise testing, risk factors, and patient subjective assessment of the exertion symptoms. During training all patients were supervised and data were recorded by medical staff, and walking speed was, if necessary, adapted to bearable dyspnea and optimal oxygen saturation. The range for the rating of perceived exertion was set at 12 to 14 (moderate to somewhat difficult/hard) on a 0-to-20 Borg Scale.[32]

The control group

The CCVR program was basically identical to the NW program. The only difference was that in the control group the main part of the aerobic training consisted of traditional walking without poles instead of NW (Table I).

Measures

Primary outcomes

Cardiovascular performance and exercise capacity assessments were carried out using a stationary cycle ergometer (Ergoline Ergoselect 200P). The bicycle work has been quantified in watts (W). METs capacity was calculated from the symptom-limited bicycle test, and 2-D echocardiography was used to determine ejection fraction (EF) by the planimetric method.

Functional capacity was assessed with a standard 6MWT on a measured indoor track.[30] Patients were instructed to walk as far as possible without Nordic poles for 6 minutes, but not to run or jog. At 1, 3 and 5 minutes of the 6MWT, participants were informed of the time remaining. Distance walked was measured in meters.

Secondary outcomes

Health-related quality of life (HRQoL) was measured using the 36-item Short Form Health Survey (SF-36). The SF-36 scale is used internationally as a generic measure of self-reported physical and mental HRQoL.[31] It consists of 36 items covering eight primary dimensions of subjective health perceptions. These include physical functioning, role limitations due to physical problems, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems, and mental health. Subscale scores and summary scores, the Physical Component Summary (PCS) and Mental Component Summary (MCS), were calculated using published algorithms, in which higher scores indicate better functioning. The algorithms included the following standardized three-step procedure. First, all eight subscale scores (range 0-100) were standardized using means and standard deviations from the general US population. Second, they were aggregated using weights from the general US population. Finally, aggregate PCS- and MCS-scores were standardized using a linear T-score transformation (mean, 50±10). The SF-36 scale has been well tested and has been proven to have satisfactory psychometric properties and international comparability also among cardiac patients.[35]

TABLE I.—*Description of the aerobic workload duration in the intervention (NW) and control (CCVR) group.*

Activity	NW group (time/week)	CCVR group (time/week)
Stationary bicycle	30 min	30 min
Hydrokinesiotherapy	30 min	30 min
Standard walking	-	160 min
Nordic walking	160 min	-
Overall duration	220 min	220 min

NW: Nordic walking; CCVR: conventional cardiovascular rehabilitation program.

Statistical analysis

The analyses were based on the intention-to-treat principle. In order to analyze the data, descriptive and inferential statistics were used. Categorical variables were described as frequencies and percentages. Continuous variables were tested for normality and presented as mean and standard deviation. Independent samples *t*-tests for continuous variables and Chi–square tests and confidence interval analysis tests for categorical variables were used to compare the intervention (NW) and the control (CCVR) group at baseline. The differences between the intervention and the control groups at the time before the intervention (T1: baseline) and 3 weeks after the intervention (T2: follow-up) were evaluated using the generalized estimating equations (GEE). The GEE is a semi-parametric statistical approach to fit a marginal model for longitudinal/clustered data analysis. It is used to estimate the parameters of a generalized linear model with a possible unknown correlation between outcomes. In our study, variables "group" (NW *vs.* CCVR) and "time" (T1, T2) were used as factors. The missing data for patients who were lost to follow-up at T2 (post training data) were estimated using maximum likelihood estimation by the automatic regression imputation method within the GEE analysis. To determine the effect size (ES) Cohen's *d* was used. According to Cohen, interpretation of effect sizes is as follows: d=0.2 represents a small effect size, 0.5 a medium effect size, and 0.8 a large effect size.[36] Calculations were performed using IBM SPSS v. 26 for Windows (IBM, Chicago, IL, USA). The level of statistical significance was set at $P<0.05$.

Results

Patient characteristics and baseline data

A total of 114 consecutive patients were assessed for eligibility. Twenty-four of the eligible patients (21.1%) did not meet the inclusion criteria and were excluded. Four patients (3.5%) refused to participate. The remaining 86 patients (95.5% RR-response rate) consented with participation in our study and were assigned in 2:1 ratio into two groups: 54 patients to the NW group and 32 patients to the control CCVR group (Figure 1). There were no baseline sociodemographic differences found between the groups, as well as no differences in CAD-related symptoms, risk factors or primary and secondary measures (Table II).

Overall, 83 of the participants completed the study (effective RR 92.2%), 53 of whom were assigned to the NW group and 30 to the control group. The reasons for not completing the study were as follows: two patients developed upper respiratory tract infection and one was unable to finish the study due to family reasons (Figure 1).

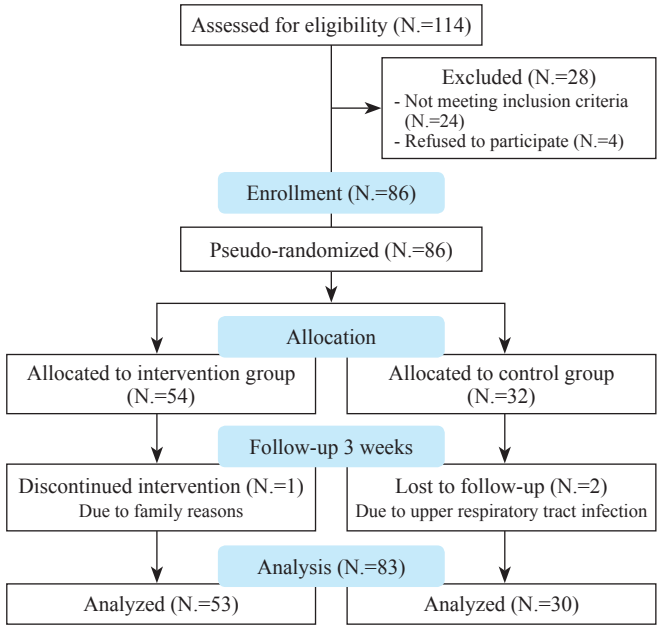

Figure 1.—Study flowchart.

TABLE II.—*Patient characteristics and baseline data.*

Characteristics	Total sample	NW group	Control group	P value	95% CI
N. subjects	83 (100%)	53 (63.9%)	30 (36.1%)		
Age (years)	59.5±7.0	59.1±7.0	60.4±7.0	0.403	-4.520; 1.833
Sex, men	64 (77.1%)	42 (79.2%)	22 (73.3%)	0.538	-0.133; 0.251
Secondary education	72 (86.7%)	44 (53.0%)	28 (33.7%)	0.183	-0.238; 0.032
University education	11 (13.3%)	9 (10.8%)	2 (2.4%)	0.183	-0.032; 0.238
Weight (kg)	84.3±12.1	85.8±12.1	81.6±11.8	0.124	-1.189; 9.687
Height (m)	1.7±0.1	1.8±0.1	1.7±0.1	0.074	-0.003; 0.073
BMI (kg/m²)	28.6±3.6	28.7±3.6	28.4±3.5	0.726	-1.339; 1.915
SBP (mmHg)	128.7±14.1	128.8±14.3	128.5±14.0	0.933	-6.186; 6.733
DBP (mmHg)	78.7±7.2	78.7±.8	78.5±6.2	0.881	-3.056; 3.556
NYHA I.	22 (26.5%)	13 (15.7%)	9 (10.8%)	0.587	-0.255; 0.146
NYHA II.	52 (62.6%)	35 (42.2%)	17 (20.5%)	0.396	-0.125; 0.312
NYHA III.	9 (10.8%)	5 (6.0%)	4 (4.8%)	0.583	-0.184; 0.106
Beta blockers	70 (84.3%)	45 (54.2%)	25 (30.1%)	0.850	-0.149; 0.180
Statins	81 (97.6%)	52 (62.7%)	29 (34.9%)	0.680	-0.051; 0.088
Antiplatelet drugs	81 (97.6%)	53 (63.9%)	28 (33.7%)	0.057	-0.023; 0.156
Aspirin	81 (97.6%)	51 (61.4%)	30 (36.1%)	0.281	-0.089; 0.014
PCI	56 (67.5%)	35 (42.2%)	21 (25.3%)	0.711	-0.247; 0.168
CABG	27 (32.5%)	18 (21.7%)	9 (10.8%)	0.711	-0.168; 0.247
Ergometry (W)	120.9±31.3	120.3±30.2	122.7±33.8	0.808	-16.322; 12.761
EF (%)	49.4±7.6	50.0±7.6	48.3±7.5	0.351	-1.859; 5.170
METs	6.3±1.3	6.2±1.3	6.6±1.3	0.208	-0.972; 0.215
6MWT (m)	512.9±80.5	524.5±85.6	494.0±68.7	0.102	-6.244; 67.275
PCS, SF-36	39.5±9.1	39.6±9.8	39.2±9.5	0.880	-5.443; 6.328
MCS, SF-36	46.9±9.5	47.0±10.3	46.6±8.0	0.886	-5.719; 6.602

The displayed values are mean±SD for continuous variables, and frequencies and percentages for categorical variables. Independent samples *t*-tests were used for continuous variables, and chi-square tests and confidence interval analysis tests were used for categorical variables.
The missing cases for the outcome measures at T2 were as follows: 2.4% ergometry, METs; 4.8% EF, 6MWT.
NW: Nordic walking; BMI: Body Mass Index; SBP: systolic blood pressure; DBP: diastolic blood pressure; PCI: percutaneous coronary intervention; CABG: coronary artery bypass graft; NYHA: New York Heart Association; EF: ejection fraction; METs: metabolic equivalents of tasks; 6MWT: Six-Minute Walking Test; SF-36: Short Form Health Survey Questionnaire; PCS: Physical Component Summary; MCS: Mental Component Summary.

Primary outcome measures

Feasibility of NW

The acute physiological responses to walking were assessed before and after each training session. All patients achieved the pre-set goal for maximum HR to ensure training efficiency (>75% of the initial maximum HR), even though walking at different speed levels according to the severity of CAD. The rating of perceived exertion in participants was within the mild/moderate range (12 to 14 points) on the 0-20 Borg Scale.[32] No significant arrhythmias or marked hypertensive and pulse response to exertion were detected during or shortly after the exercise sessions. None of the patients had any difficulties in performing Nordic walking adequately. No other (serious) adverse events were reported.

Cardiovascular and functional performance

After the three-week training period, significant differences in overall cardiovascular performance were reported in favor of the NW group. Cardiovascular performance, as assessed by exercise ergometry, increased by 14 W (+11.0%) in the NW group and by 4 W (+3.2%) in the control group compared to baseline (Table III). The difference in change (Δ) between the NW and control group after the training program was statistically significant (Wald χ^2=5.869, P<0.05) with a small effect size (ES), Cohen's *d*=0.478. Also, tolerance of physical activity, expressed in achieved METs, was significantly better in the NW group compared to controls (ΔMETs: +9.8% *vs.* +1.5%, Wald χ^2=9.347, P<0.01, medium ES, *d*=0.565). Finally, functional capacity, as measured by performance on the 6MWT, was significantly better in the NW group compared to controls (Δ6MWT: +8.3% *vs.* +5.1%, Wald χ^2=5.013, P<0.05, small ES, *d*=0.468). There were no significant differences detected in changes in EF.

Secondary outcome measures

HRQoL

Changes in the SF-36 PCS in the NW and control group compared to baseline and between the groups were non-significant (ΔPCS: +1.5 *vs.* +4.6, P=0.425). Likewise, no significant differences were found in the SF-36 MCS (ΔMCS: -0.4 *vs.* +2.2, P=0.400) (Table III). Lastly, no significant differences between the NW group and the control group were identified in any of the eight SF-36 dimensions (not presented in table).

Discussion

The aim of this pseudo-randomized controlled trial was to determine whether a NW program could safely and effectively increase cardiovascular performance and quality of life in patients with coronary artery disease compared to a CCVR program. We hypothesized that increasing the exercise intensity using NW poles may allow individuals to obtain greater physiological benefits from their walking program. The results of this study show that Nordic walking had clinically important effects, above and beyond standard cardiac rehabilitation, on cardiovascular and functional capacity. The effectiveness of NW on improving quality of life outcomes could not be confirmed satisfactorily, however.

To the best of our knowledge, this is the first study that compares meticulously the effects of Nordic walking with

TABLE III.—*Mean scores and statistical comparison of the intervention and control groups before and after the training (3 weeks).*

Parameter	Group	T1 (baseline)		T2 (follow-up)		% change	Wald χ^2	P value	Effect size	
		EMM	(SE)	EMM	(SE)				Cohen's *d*	Interpretation
Ergometry (W)	NW	120.3	(4.1)	134.3	(4.7)	+11.6	5.869	0.015	0.478	Small
	Control	122.1	(6.2)	126.0	(6.3)	+3.2				
EF (%)	NW	50.0	(1.1)	50.6	(1.0)	+1.0	1.383	0.240	0.278	NS
	Control	48.3	(1.4)	49.7	(1.3)	+2.6				
METs	NW	6.2	(0.2)	6.8	(0.2)	+9.8	9.347	0.002	0.565	Medium
	Control	6.6	(0.2)	6.7	(0.2)	+1.5				
6MWT (m)	NW	524.4	(12.1)	568.3	(12.3)	+8.3	5.013	0.025	0.468	Small
	Control	493.9	(12.3)	519.1	(12.7)	+5.1				
PCS, SF-36	NW	39.7	(1.6)	40.3	(1.4)	+1.5	0.637	0.425	0.255	NS
	Control	39.2	(2.4)	41.0	(2.4)	+4.6				
MCS, SF-36	NW	46.6	(1.9)	46.5	(1.8)	-0.4	0.708	0.400	0.255	NS
	Control	46.6	(2.0)	47.6	(2.0)	+2.2				

NW: Nordic walking; EMM: estimated marginal mean; SE: standard error; EF: ejection fraction; METs: metabolic equivalent of tasks; 6MWT: Six-Minute Walking Test; SF-36: Short-Form Health Survey Questionnaire; PCS: Physical Component Summary; MCS: Mental Component Summary; NS: not significant.

traditional walking training of the same duration on exercise capacity, physical fitness, and health-related quality of life in men and women with CAD. The effects of Nordic walking on functional capacity observed in the present study can be compared with previous reports in similar patient groups. A study by Kocur *et al.* showed that a 3-week program of Nordic walking improved the 6MWT distance by 83 m (+14.3%) compared to baseline in men with CAD with good exercise tolerance participating in an inpatient cardiac rehabilitation program.[25] The improvements in our study were lower (+44 m, 8.3%), which can be explained by gender differences (mixed sample vs men only) and/or differences in patients' functional status; the mean walking distance in our sample was shorter at baseline. Furthermore, in our study the improvements in tolerance of physical activity, expressed in achieved METs, improved by 9.8% in the NW group and by 1.5% in the control group. In Kocur's *et al.* study the tolerance of physical activity was +21% in the NW+CCVR group, +19% in the traditional walking (TW)+CCVR group, and +7% in the CCVR group. Our results can also be compared to a study by Wilk *et al.* contrasting an NW+CCVR (Δ METs: +30.4%) group with a CCVR group only (+14.1%).[26] These earlier CAD studies, however, do not provide any information on the statistical significance of the difference in changes within and between the groups simultaneously. Another criticism of these earlier studies is that NW was administered in combination with CCVR programs, possibly resulting in an additive effect due to the increased workout volume rather than the specific type of intervention.[24]

Our findings can also be related to findings in other cardiovascular diseases (CVD), such as peripheral arterial disease (PAD), heart failure and post-stroke survivors. A study by Bulinska *et al.* reported a +3.4% increase in 6MWT distance in NW groups compared to a +1.9% increase in a control group (traditional treadmill training) in PAD patients following a 12-week walking training program.[37] A study by Spafford *et al.* reported larger changes in exercise duration and oxygen uptake (peak VO_2) in NW groups compared with controls in PAD patients.[38] In contrast, a study by Collins *et al.* found traditional walking to be superior to NW in increasing walking endurance on a constant work rate treadmill test for patients with PAD.[39] In patients with heart failure, significant differences between NW and CCVR participating in a 12-week outpatient cardiac rehabilitation training were found in functional capacity (Δ6MWT: +29.2% *vs.* +11.3%, respectively).[40] Likewise, a 12.2% improvement in 6MWT distance in an NW group compared to a 5.9% increase in a CVVR group was observed in patients with heart failure participating in an 8-week home-based telemonitored NW training program.[41] Finally, a statistically significant difference in 6MWT distance was observed in favor of NW performed on a treadmill — +23% in a study by Kang *et al.*[42] and +16% in a study by Shin *et al.*[43] — compared with traditional treadmill training without arm swing (+10% and +1%, respectively) in post-stroke survivors after 4-6 weeks of training.

Along these lines comes an interesting observation regarding the incongruence between the perceptual and metabolic loads in the NW as compared to traditional walking. In line with our observations, several previous studies showed that the heart rate and oxygen consumption were higher in NW, while the rating of perceived exertion was similar.[44, 45] Or alternatively, as a recent study by Gomeñuka *et al.* shows when the exercise intensity was strictly controlled and individualized (using percentages of anaerobic threshold), the rating of perceived exertion was lower in NW group.[14] This mismatch between the two measures — which likely explains the higher adaptations from NW than traditional walking training — offers an exciting alternative for improving cardiorespiratory fitness in the health context as well as wider application in health promotion in various population groups.[14, 44]

Psychological distress and depressive symptoms are a major problem for patients with cardiovascular disease, and the presence of these factors are known to be predictors of increased risk of adverse cardiac event.[46] Previous studies have shown that NW can have beneficial effects on reducing depressive symptoms and also on improving the physical component of quality of life in patients with cardiovascular disease,[41, 42, 47] although a later study by Collins *et al.*[39] did not find improvements in QoL, as measured by the SF-36, in patients with peripheral arterial disease. Our study did not confirm significant improvements in QoL either. This could be due to the short duration of training: a 3-week intervention program in our study as compared to a 24-week program of the study by Collins *et al*.[47] and an 8-week program in a study by Piotrowicz *et al.*[41] It could also be explained by differences in settings; home-based intervention vs institution-based intervention, which can be more stressful for patients. Another explanation might be that the SF-36 as a generic scale is not sensitive enough to detect subtle changes in quality of life in CVD patients.[48] This assumption can also be supported by non-significant differences in the mental component of QoL in the original study by Collins *et al.* and the non-significant differences in both components of the SF-36 in their later study.[39, 47]

Strengths and limitations of the study

Strengths of our study lie in its high response rate (96%), robust methodology (judicious sample size selection, both genders, using structured training protocols to objectively quantify the benefits of NW training) and multivariate analyses (simultaneously testing between subjects and within subject effects, *i.e.* comparisons between groups and over time). The main limitations relate to the lack of blinding and the short follow-up period. A lack of participant blinding, which is generally not feasible in these types of behavioral intervention studies, can lead to issues of intervention contamination. We evaluated outcomes after a 3-week training program, while the long-term effects of Nordic walking remain unclear.

Practical implications

NW produces greater cardiovascular strain, which is good for people who can walk, but who have trouble reaching their optimal loading zone by regular walking. The minimal rehabilitation period in which noticeable changes occur has also been discussed. Our study shows that only three weeks of rehabilitation significantly increases cardiovascular performance in CAD patients. Our study also confirms that early initiation of physical therapy has paramount physiological and physical benefits for patients. In this period, patients are adapting to new exercise tolerance limitations and forming behavioral attitudes toward their illness. Furthermore, walking with poles improves stability and joint loading, which makes this type of exercise suitable also for other population groups, such as elderly people as well as patients with orthopedic impairments and balance problems.

Conclusions

A three-week, supervised Nordic Walking (NW) training program has proven to be an accessible, safe and effective cardiac rehabilitation exercise for improving cardiovascular and functional performance in CAD patients. NW can be considered to be a beneficial low-threshold physical activity, which seems to be particularly well suited for permanent implementation in people with limited resources and limited functional and motivational capacities.

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