Clinical Rehabilitation 2009; **23:** 995–1004

Effects of Nordic Walking training on exercise capacity and fitness in men participating in early, short-term inpatient cardiac rehabilitation after an acute coronary syndrome – a controlled trial

Piotr Kocur Department of Kinesiotherapy, **Ewa Deskur-Śmielecka**, **Małgorzata Wilk** and **Piotr Dylewicz** Department of Cardiac Rehabilitation, University School of Physical Education, Poznań, Poland

Received 13th January 2009; returned for revisions 15th March 2009; revised manuscript accepted 17th April 2009.

Objective: To investigate the effects of Nordic Walking training supplemental to a standard, early rehabilitation programme on exercise capacity and physical fitness in men after an acute coronary syndrome.
Design: A controlled trial.
Setting: Cardiac rehabilitation service of a provincial hospital.
Subjects: Eighty men 2–3 weeks after an acute coronary syndrome, with good exercise tolerance.
Interventions: Three-week, inpatient cardiac rehabilitation programme (control group) supplemented with Nordic Walking (Nordic Walking group), or with traditional walking training (walking training group).
Main measures: Exercise capacity was assessed as peak energy cost (in metabolic equivalents) in symptom-limited treadmill exercise test, and physical fitness with the Fullerton Functional Fitness Test.
Results: Exercise capacity after the rehabilitation programme was higher in the Nordic Walking group than in the control group (10.8 ± 1.8 versus 9.2 ± 2.2 metabolic equivalents, $P = 0.025$). The improvement in exercise capacity in the Nordic Walking group was higher than in the control group (1.8 ± 1.5 versus 0.7 ± 1.4 metabolic equivalents, $P = 0.002$). In contrast to the control group, the results of all components of the Fullerton test improved in the Nordic Walking and walking training groups. After the programme, lower body endurance, and dynamic balance were significantly better in the Nordic Walking group in comparison with the walking training and control groups, and upper body endurance was significantly better in the Nordic Walking and walking training groups than in the control group.
Conclusions: Nordic Walking may improve exercise capacity, lower body endurance and coordination of movements in patients with good exercise tolerance participating in early, short-term rehabilitation after an acute coronary syndrome.

Address for correspondence: Piotr Kocur, Department of Kinesiotherapy, University School of Physical Education, Ul. Królowej Jadwigi 27/39, 61–871 Poznań, Poland.
e-mail: p.kocur1@wp.pl

10.1177/0269215509337464

Introduction

Increase in physical activity and improvement in exercise capacity are important aims in primary and secondary prevention of cardiovascular disease.[1,2]

There is extensive evidence that walking training increases exercise capacity and fitness in healthy individuals, as well as in patients with various chronic diseases.[3–7] It has been also shown that walking has favourable metabolic and psychological effects.[6–10] Nordic Walking is a relatively new type of walking training, which is based on marching using sticks adopted from cross-country skiing. The main purpose of using the sticks is to involve muscles that are not used during normal walking. This enables high intensity exercises to be performed at a relatively low level of perceived exertion. The effectiveness of Nordic Walking in increasing physiologic parameters such as peak oxygen uptake and muscular endurance in the general population is well documented.[11,12]

In cardiac rehabilitation programmes, physical training is usually based on endurance training on treadmill or cycle ergometer, complemented with resistance training. Additionally, calisthenics are performed, and unsupervised, patient-guided walking is recommended.[13,14] Despite its well-documented efficacy in cardiovascular prevention, traditional walking training is underestimated and unpopular in cardiac rehabilitation setting.[10] Nordic Walking seems to be a promising option for cardiac rehabilitation, because of the engagement of the upper part of the body, and relatively high energy expenditure at low exercise intensity. However, Nordic Walking in patients with cardiovascular disease has rarely been investigated. It has been found in a small study involving patients participating in late cardiac rehabilitation that the use of poles can safely increase energy expenditure during walking training.[15] The results of a pilot study performed in subjects during the second phase of rehabilitation after an acute coronary syndrome suggested that Nordic Walking could improve exercise capacity in such patients.[16]

We hypothesized that inclusion of Nordic Walking in a standard cardiac rehabilitation programme would result in greater improvement in exercise capacity and physical fitness in comparison with standard training or standard training supplemented with traditional walking training. To this end, we investigated changes in exercise capacity and physical fitness in three groups of men with good exercise tolerance participating in short-term, early inpatient cardiac rehabilitation after an acute coronary syndrome.

Methods

The study was performed in the cardiac rehabilitation service of a provincial hospital, and was carried out over two years, eight months per year (from April to November). Each month the first five men who met the qualification criteria and who agreed to participate in the study were enrolled. The inclusion criteria were: (1) an acute coronary syndrome treated with primary percutaneous coronary intervention 2–3 weeks earlier, (2) exercise tolerance >6 metabolic equivalents in symptom-limited electrocardiography treadmill exercise test performed on admission to the cardiac rehabilitation centre, (3) ejection fraction by echocardiography $\geq$40%. The exclusion criteria were: previous episodes of cardiac arrest, uncontrolled arrhythmias, chronic or acute inflammation, diabetes on insulin treatment, liver or renal failure, and neoplastic disease. The qualification criteria were chosen for safety reason, as patients were to exercise outdoor at a distance from the hospital under the supervision of a physiotherapist.

Each month one of three training modalities: standard training (without walking training), standard training supplemented with traditional walking training, or standard training supplemented with Nordic Walking was realized in the rehabilitation service. The type of training for particular month was selected at the beginning of the month (before recruitment of patients), by blind selection of 1 of 16 envelopes ($8 \times$ Nordic Walking, $4 \times$ walking training and $4 \times$ standard training). Consecutively, patients enrolled in the study were allocated to one of three groups: Nordic Walking group (40 patients), walking training group (20 patients), or control group (C group; 20 patients).

The study protocol was accepted by the local ethics committee.

Rehabilitation programme

The rehabilitation programme lasted for three weeks and included 12–13 sessions. Patients in the control group participated in a standard rehabilitation programme based on endurance training on a cycle ergometer and calisthenics (five times per week). The standard rehabilitation programme was planned so that the weekly energy expenditure of training was 1250–1500 kcal, in accordance with the American College of Sports Medicine guidelines.[17] In addition to the standard rehabilitation programme (cycle ergometer and calisthenics), patients in the Nordic Walking group were involved in Nordic Walking training (five sessions per week), and subjects in the walking training group participated in supervised, traditional walking training (without poles; five times per week).

Calisthenics

Each session began with warm-up (5 minutes) and ended with cool-down (5 minutes). All exercises were performed in standing position. Special attention was given to stretching and breathing exercises. The scheme of the calisthenics session was identical in all study groups. In the Nordic Walking and walking training groups, calisthenics were performed directly before walking training. Mean exercise session duration was 30 minutes 39 seconds.

Cycle ergometer training

Cycle ergometer training was of continuous mode, and the training load was chosen based on the patient's heart rate. Each session began with 2–3 minutes warm-up, and ended with 2–3 minutes cool-down. The main part lasted for 16 minutes. During the first two sessions, the training load was chosen so that patient's heart rate was 40% of the heart rate reserve calculated from the resting and peak heart rate during the ergometry performed on admission to the rehabilitation centre. On the following days, training intensity was increased to 60% of the heart rate reserve. The mean session duration was 20 minutes 54 seconds.

Nordic Walking

As none of the patients had ever performed Nordic Walking, a 15-minute instruction was given on the first day of training, and subjects were taught the basic Nordic Walking technique according to the recommendations of the International Nordic Walking Association (INWA).[11] On the following day, patients participated in their first group Nordic Walking training session. The Nordic Walking sessions were held directly after calisthenics, as a warm-up. The training was performed outdoors on a flat asphalt surface, under the supervision of a qualified physiotherapist. The distance was established manually with a 10-m measure. The total distance covered during one session was 2.5 km. Halfway through there was a 5-minute break for stretching and breathing exercises.

Walking training

Walking training was performed in a way similar to Nordic Walking training, directly following calisthenics session (warm-up). Patients walked outdoors, under the supervision of a physiotherapist, without using poles. The total walking distance was 2.5 km.

Energy expenditure

The energy expenditure during each form of walking training was calculated two ways: from continuous heart rate recording with heart rate monitor (Polar s610i, Polar Electro Oy, Finland) and data from the initial electrocardiographic exercise test, and based on data on physical activity monitoring with a belt accelerometer (Caltrac, Muscle Dynamic Fitness System, CA, USA). The assessment of energy expenditure with these methods is very approximate, but the estimations were only made to investigate differences between both training methods, and not to obtain reliable absolute values. For each type of training, energy expenditure was assessed four times with both methods simultaneously, and mean values for each method were calculated. In addition, patients' perceived exertion during walking training was assessed using the Borg Scale at least once during the programme.

For both types of walking training (Nordic Walking and traditional walking) percentage of training time spent on exercise of given intensity was assessed based on recordings from the heart rate monitor, and data on resting and peak heart rate during the baseline exercise test.

Assessment of exercise capacity and physical fitness

Exercise capacity

Exercise capacity was assessed with a symptom-limited treadmill exercise test following the modified Bruce protocol.[18] This protocol involves the incline of the treadmill, and the speed increased at 3-minute intervals. The modified Bruce protocol starts at a lower workload than the standard test (third stage of modified protocol corresponds to the first stage of standard Bruce protocol). The test was performed twice: on admission (on the first, or on the second day), and at the end of the rehabilitation programme (on the last, or on the next to last day). The outcome was peak energy cost (expressed in metabolic equivalents, METs). The physician performing exercise test was blind as to the group of the patient.

Physical fitness

Physical fitness was determined with the Fullerton Functional Fitness Test.[19–21] The test was performed at the beginning, and at the end of the rehabilitation programme, on the other day than that on which the treadmill exercise test was performed. The Fullerton Functional Fitness Test was preceded by a short warm-up, and consisted of six components performed in the following order:

1) arm curl
2) chair stand
3) back scratch
4) chair sit and reach
5) up and go
6) 6-minute walking test (6MWT).

The physiotherapist performing the Fullerton test was blind as to the group of the patient.

Statistical analysis

The distribution of continuous data was assessed with the Shapiro–Wilk test. As data were not normally distributed, the comparisons between the two study groups were assessed with Mann–Whitney test, and between the three study groups with Kruskal–Wallis ANOVA. For paired variables, the Wilcoxon test was used. *P*-value <0.05 was considered significant.

Results

The basic characteristics (age, body mass index, treatment and exercise capacity) of the patients in the three study groups were very similar (Table 1). All patients enrolled in the study completed the training programme, and no adverse events were observed.

Table 2 presents comparisons of Nordic Walking and walking training sessions. Session duration and energy expenditure assessed with a heart rate monitor were similar for both types of training, while energy expenditure assessed with an accelerometer was higher, and rate of perceived exertion was lower during Nordic Walking. Percentages of training time spent on exercise of given intensity during Nordic Walking and walking training were similar.

Exercise capacity assessed with treadmill exercise test (metabolic equivalents) significantly improved following the rehabilitation programme in the Nordic Walking and walking training groups, but not in the control group (Table 3). Exercise capacity after the rehabilitation programme was significantly higher in patients participating in Nordic Walking training in comparison with subjects in the control group. The change in physical capacity in the Nordic Walking group was significantly higher than the change in the control group.

Before the rehabilitation programme, patients in all three groups did not differ with regard to their physical fitness level (Table 4; $P = \text{NS}$ for all comparisons between groups during baseline assessment). The results of all components of the Fullerton test improved in patients in the Nordic Walking and walking training groups,

Table 1 Basic characteristics of the study groups – mean (SD)

	Nordic Walking group ($N=40$)	Walking training group ($N=20$)	Control group ($N=20$)
Age (years)	51.4 (6.2)	51.3 (7.1)	54.5 (9.4)
Body mass index	28.6 (3.3)	28.3 (3.0)	27.7 (2.0)
Time after acute coronary syndrome (days)	19.2 (2.0)	19.8 (1.6)	18.8 (1.8)
Beta-blocker treatment (% of patients)	100	100	100
Exercise capacity (metabolic equivalents in treadmill exercise test)	8.9 (2.0)	8.4 (1.9)	8.6 (1.9)

$P=$NS for all comparisons between the groups.

Table 2 Characteristics of Nordic Walking and traditional walking training sessions

	Nordic Walking	Walking training
Session duration (mean)	29 min 49 s	31 min 18 s
Energy expenditure by accelerometer (kcal), mean (SD)	213.37 (32.8)**	183.8 (27.2)
Energy expenditure by heart rate monitor (kcal), mean (SD)	255.67 (85.6)	278.23 (74.5)
Borg scale – median (IQR)	13 (13, 13)*	14 (13, 14)
Percentage of time at maximal intensity exercise (85–100% heart rate reserve[a])	3%	4%
Percentage of time at high intensity exercise (60–85% heart rate reserve)	21%	21%
Percentage of time at moderate intensity exercise (40–60% heart rate reserve)	36%	36%
Percentage of time at low intensity exercise (20–40% heart rate reserve)	32%	32%
Percentage of time at very low intensity exercise (0–19% heart rate reserve)	8%	7%

[a]Heart rate reserve calculated from resting and peak exercise heart rate.
*$P=0.008$ versus walking training.
**$P<0.001$ versus walking training.

Table 3 Exercise capacity (in metabolic equivalents) before and after rehabilitation programme: results of treadmill exercise test following the modified Bruce protocol

	Baseline test	End test	Wilcoxon	Difference
Nordic Walking group	8.9 (2.0)	10.8 (1.8)*	$P<0.0001$	1.8 (1.5)*
Walking training group	8.4 (1.9)	10.0 (1.9)	$P<0.0001$	1.6 (1.9)
Control group	8.6 (1.9)	9.2 (2.2)	NS	0.7 (1.4)

Data are shown as mean (SD).
*$P<0.05$ versus control group.

while in subjects in the control group the improvement was observed exclusively in the 6-minute walk distance and 'chair stand' test. The results of 'chair stand', and 'up and go' tests after the rehabilitation programme were significantly better in the Nordic Walking group than in the walking training and C groups. After the rehabilitation programme, patients in both groups with walking training (Nordic Walking and walking training groups) had significantly better results in the 'arm curl' test than the control group.

Discussion

This study was designed to investigate the effect of Nordic Walking training on exercise capacity and physical fitness in patients participating in early, short-term, stationary cardiac rehabilitation after an acute coronary syndrome. The main finding was that implementation of Nordic Walking in a standard three-week, inpatient cardiac rehabilitation programme resulted in improved exercise capacity assessed with the treadmill exercise test (metabolic equivalents) after the rehabilitation

Table 4 Physical fitness before and after rehabilitation programme: the results of the Fullerton Functional Fitness Test

Functional fitness test	Group	Baseline test	End test	Wilcoxon
6MWT (m)	NW	580.2 (62.9)	663.0 (77.0)	$P<0.0001$
	WT	544.2 (78.9)	595.0 (56.1)	$P=0.0007$
	C	536.0 (66.4)	604.5 (78.5)	$P=0.0002$
Arm curl (repetitions)	NW	22.3 (4.6)	25.9 (4.8)***	$P<0.0001$
	WT	20.3 (4.5)	23.7 (5.1)*	$P=0.0038$
	C	17.8 (4.0)	20.0 (4.6)	$P=$ NS
Chair stand (repetitions)	NW	17.4 (3.9)	21.2 (4.1)**#	$P<0.0001$
	WT	15.6 (4.5)	18.6 (4.9)	$P=0.0003$
	C	14.1 (3.4)	16.7 (4.8)	$P=0.012$
Sit and reach (cm)	NW	−4.5 (11.2)	−0.2 (10.3)	$P<0.0001$
	WT	−4.6 (11.6)	−2.8 (12.1)	$P=0.03$
	C	−3.3 (8.0)	−2.0 (7.3)	$P=$ NS
Back scratch (cm)	NW	−8.0 (12.2)	−6.4 (10.8)	$P=0.03$
	WT	−5.9 (11.3)	−3.0 (12.6)	$P=0.007$
	C	−12.5 (10.8)	−10.8 (9.9)	$P=$ NS
Up and go (s)	NW	4.9 (0.7)	4.4 (0.6)**#	$P<0.0001$
	WT	5.2 (0.9)	4.9 (0.7)	$P=0.02$
	C	5.2 (1.0)	5.1 (0.9)	$P=$ NS

Data are shown as mean (SD).
6MWT, 6-minute walk test; C, control; NW, Nordic Walking; WT, walking training.
$P=$ NS for all comparisons between groups during baseline assessment.
*$P<0.05$ versus control group.
**$P<0.01$ versus control group.
***$P<0.001$ versus control group.
#$P<0.05$ versus walking training group.

programme (Table 3). Incorporation of Nordic Walking to a standard rehabilitation programme also resulted in improvement in some elements of physical fitness assessed with the Fullerton Functional Fitness Test (muscle endurance of upper and lower part of the body, and dynamic balance; Table 4). To our best knowledge, the effects of Nordic Walking on exercise capacity and physical fitness in patients participating in cardiac rehabilitation have not been assessed outside our centre.

In previous studies, the physiological effects of long-term walking training in patients with cardiovascular disease have been investigated. It has been observed that a three-month, home-based traditional walking training (three times a week, 70% peak heart rate, 40–60 minutes daily) improves exercise capacity in patients with congestive heart failure.[22] Dubach *et al.* reported an increase in maximal oxygen uptake of 23% after first month, and of a further 6% following a second month of traditional walking training (2 hours daily) in men with heart failure, despite the lack of changes in cardiac output.[23] Similarly, Tenenbaum *et al.* found substantial improvement (by ~50%) in ergometry and walk test results following an 18-week training programme in heart failure patients.[24] Further improvement (by ~13%) was observed in subjects that continued the training for another 12 weeks, while in patients who discontinued exercises the results decreased by ~27% during the follow-up. These findings suggest that the most marked improvement in exercise capacity is gained in short time after implementation of walking training. In accordance with these findings, we observed significant improvement in exercise capacity after only three weeks of both traditional walking and Nordic Walking training (exercise test: increase by 20% in the Nordic Walking group, and by 14% in the walking training group; 6-minute walk distance: increase by 16% in the Nordic Walking group, and by 13% in the walking training group; Tables 3 and 4).

In our previous study investigating the effects of standard, short-term, early stationary cardiac rehabilitation (without walking training) on exercise capacity measured with 6-minute walk distance in patients with heart failure after an acute coronary syndrome, we observed 10% improvement (from 406–443 m).[25] Similar improvement was found in the present study, involving patients with relatively good exercise tolerance. It should be emphasized, however, that the increase in the walked distance expressed in absolute values (metres) was much higher in the present study (83 m in the Nordic Walking group, and 68 m in the walking training group). Such improvement should be considered clinically significant according to the American Thoracic Society, and indicates high effectiveness of the training programme.[26] Moreover, it was found by Meyer *et al*. that the degree of improvement in walking performance was inversely related to the initial 6-minute walk distance; in patients with lowest walking performance (232 m), a spectacular improvement by 65% was observed.[27] Of note, patients in the Mayer *et al*. study participated in regular treadmill training.

The results of the Fullerton Functional Fitness Test demonstrate that inclusion of walking training, and especially Nordic Walking, into a standard cardiac rehabilitation programme has a favorable effect on patients' physical fitness level. The results of all components of the Fullerton test improved significantly in patients subjected to Nordic Walking and traditional walking training, while in the control group the improvement was found only for 6-minute walk distance and lower body endurance (Table 4). The results of the 'up and go' and 'chair stand' tests performed at the end of the rehabilitation programme were significantly better in the Nordic Walking group compared with the patients involved in traditional walking. Similar improvements in all components of the Fullerton Test were reported by Parkatti *et al.* in a study investigating the effects of a 12-week Nordic Walking training (60 minutes, twice a week) in elderly subjects.[28] These findings suggest that Nordic Walking is a type of activity that in many ways increases functional fitness level. On the other hand, previously promoted advantages of walking with poles, namely reduction of the loading of the lower limb and spinal joints (especially knee joints) are currently called into question. The results of recent studies indicate that Nordic Walking does not reduce the load on the knees compared with walking without poles, and in certain situations the load on the knee joint may be even increased.[29–31] According to Hagen *et al*., Nordic Walking is associated with slight load on the lower limb, but high wrist accelerations may cause overuse injuries of upper limb joints.[32] In our study population, in which the training intensity was thoroughly adjusted to patients' performance, we observed no overuse injuries. Despite these reservations, favourable effects of Nordic Walking on functional fitness and quality of life have been noted in the rehabilitation of patients with a wide spectrum of diseases, including Parkinson's disease, chronic lower back pain and rheumatic diseases.[15,33–36]

Kukkonen-Harjula *et al*. compared the effects of Nordic Walking and traditional walking training in sedentary, middle-aged women with a neuromuscular fitness test battery assessing several motor skills, such as one-leg standing balance, dynamic balance in backwards walking, neck–shoulder mobility, leg strength in the one-leg squat, and dynamic upper arm extension.[37] They observed significant improvements in both study groups. Despite the fact that the triceps is strongly engaged in muscular work during Nordic Walking, the improvement in the dynamic upper arm extension test in the Nordic Walking group was similar to that found in women subjected to traditional walking training. Similarly, Karavan observed that Nordic Walking training resulted in an increase in upper body muscle endurance in triceps lateral pulldown, but did not increase muscular strength (assessed with triceps pushdown and a modified lateral pulldown).[38] Muscular endurance improved in the Nordic Walking group by 37%, and by 14% in the traditional walking group. These findings are in accordance with the results of our study, in which upper body muscular endurance (assessed with 'arm curl') increased in both Nordic Walking and walking training groups, and was significantly better than in the control group (Table 4). It should be emphasized that elbow flexors are the muscles predominantly engaged in the arm curl test. The lack of differences between the Nordic Walking and walking training groups may, at least partially, be caused by the fact that patients walked using the basic Nordic Walking technique, in which full extension of the elbow was not performed. Improvement in the arm curl test suggests strong engagement of the elbow flexors during fast walking, independent of using the poles. In the study of Kukkonen-Harjula *et al.*, the increase in leg strength in patients participating in the walking training was bigger than that in the Nordic Walking group.[37] In contrast, in our study population leg muscular endurance ('chair stand') was highest in the Nordic Walking group. Presumably, in our patients the engagement of the leg muscles (espescially eccentric work of quadriceps femur) in loading response during stance phase of gait was stronger while walking with poles than during traditional walking. Patients in the Kukkonen-Harjula *et al.* study walked using the full technique, which was probably associated with more proportional distribution of joint load.

The 'up and go' test is an indirect measure of coordination of movement and dynamic balance. The time of 'up and go' test decreased significantly in both groups subjected to the walking training, and remained unchanged in the control group (Table 4). The time of the 'up and go' test in the Nordic Walking group was significantly shorter than that in the walking training and control groups. Therefore, Nordic Walking seems to be a good training option to enhance these motor skills.

Our study has several important limitations. First, it was not a randomized study, so a selection bias cannot be ruled out. Second, the study population was not typical for inpatient cardiac rehabilitation: for safety reasons, we selected patients with good exercise tolerance, at relatively low risk. We decided also to exclude women, in order to have homogeneous groups of patients. Another limitation is that we did not measure peak oxygen uptake to assess exercise capacity. Finally, our study was of short duration, so the long-term effects of Nordic Walking on exercise capacity and physical fitness in patients participating in early cardiac rehabilitation remains to be studied.

Clinical messages

- Nordic Walking may be used as a supplement to standard rehabilitation in men after an acute coronary syndrome with good exercise tolerance.
- Nordic Walking may improve exercise capacity, lower body endurance and coordination of movements in patients participating in cardiac rehabilitation.

Funding support

The study was supported with research grant 2 P05D 05528 by the Ministry of Science and Higher Education.

References

1 World Health Organization. *Physical activity and health in Europe*. WHO Regional Office for Europe, 2006.
2 Thompson PD, Buchner D, Pina I *et al*. American Heart Association Council on Clinical Cardiology Subcommittee on Exercise, Rehabilitation, and Prevention; American Heart Association Council on Nutrition, Physical Activity, and Metabolism Subcommittee on Physical Activity. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation* 2003; **107**: 3109–16.
3 Quell KJ, Porcari JP, Franklin BA, Foster C, Andreuzzi RA, Anthony RM. Is brisk walking an adequate aerobic training stimulus for cardiac patients? *Chest* 2002; **122**: 1852–56.
4 Tully MA, Cupples ME, Chan WS, McGlade K, Young IS. Brisk walking, fitness and cardiovascular risk: a randomized controlled trial in primary care. *Prev Med* 2005; **41**: 622–62.
5 Wolszakiewicz J, Bilinska M, Foss-Nieradko B, Wrona M, Piotrowicz R. Walking training as a part of early phase of cardiac rehabilitation in patients post coronary artery bypass grafting. *Adv Rehabil* 2006; **20**: 5–10.

6 Morris J, Hardman A. Walking to health. *Sports Med* 1999; **23**: 306–32.

7 Hardman AE, Jones PR, Norgan NG, Hudson A. Brisk walking improves endurance fitness without changing body fatness in previously sedentary women. *Eur J Appl Physiol* 1992; **65**: 354–59.

8 Kelly GA, Kelly KS, Tran ZV. Walking, lipids, and lipoproteins: a meta-analysis of randomized controlled trials. *Prev Med* 2004; **38**: 651–61.

9 Kelly GA, Kelly KS, Tran ZV. Walking and resting blood pressure in adults: a meta-analysis. *Prev Med* 2001; **33**: 120–27.

10 Franklin B. Walking: the undervalued prescription. *Prev Cardiol* 2006; **9**: 56–59.

11 International Nordic Walking Association. *INWA instructor manual*, third edition. Helsinki, Suomen Latu, 2005.

12 Laukkanen R. *Review: scientific evidence on Nordic Walking. 8 December,* INWA, 2004.

13 Balady G, Ades P, Comoss P *et al*. Core components of cardiac rehabilitation/secondary prevention programs. A statement for health care professionals from the American Heart Association and the American Association of Cardiovascular and Pulmonary Rehabilitation. *Circulation* 2000; **102**: 1069–73.

14 American Association of Cardiovascular Prevention and Rehabilitation. *Guidelines for cardiac rehabilitation & secondary prevention*, fourth edition. Champaign, IL, Human Kinetics, 2004.

15 Walter PR, Porcari JP, Brice G, Terry L. Acute responses to using walking poles in patients with coronary artery disease. *J Cardiopulm Rehabil* 1996; **16**: 245–50.

16 Wilk M, Kocur P, Różańska A *et al*. Influence of Nordic Walking on exercise capacity and physical fitness in patients during second phase of rehabilitation, after an acute coronary syndrome. *Eur J Cardiovasc Prev Rehabil* 2006; **13**: S84.

17 Exercise prescription modification for cardiac patients. *ACSM's guidelines for exercise testing and prescription*, seventh edition. Philadelphia, Lippincott Williams & Wilkins, 2006.

18 Fletcher GF, Balady GJ, Amsterdam EA *et al*. Exercise standards for testing and training. A statement for healthcare professionals from the American Heart Association. *Circulation* 2001; **104**: 1694.

19 Rikli RE, Jones CJ. Assessing physical performance in independent older adults: issues and guidelines. *J Aging Phys Act* 1997; **5**: 244–61.

20 Rikli RE, Jones CJ. The development and validation of a functional fitness test for community-residing older adults. *J Aging Phys Act* 1999; **7**: 129–61.

21 Jones CJ, Rikli RE. Assessing physical performance of older adults in a community setting. *Perspectives* 2000; **2**: 128–47.

22 Oka R, de Marco T, Haskell L *et al*. Impact of a home-based walking and resistance training program on quality of life in patients with heart failure. *Am J Cardiol* 2000; **85**: 365–69.

23 Dubach P, Myers J, Dziekan G *et al*. Effect of high intensity exercise training on central hemodynamic responses to exercise in men with reduced left ventricular function. *J Am Coll Cardiol* 1997; **29**: 1591–98.

24 Tenenbaum A, Freimark D, Ahron E *et al*. Long-term versus intermediate–term supervised exercise training in advanced heart failure: Effects on exercise tolerance and mortality. *Int J Cardiol* 2006; **113**: 364–70.

25 Kocur P, Kuczma W, Wilk M *et al*. Effectiveness of a short-term rehabilitation in patients after myocardial infarction complicated with heart failure-assessment with the six-minute walk test. *Adv Rehabil* 2005; **1**: 26–30.

26 ATS statement. Guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002; **166**: 111–17.

27 Meyer K, Schwaibold M, Westbrook S *et al*. Effects of exercise training and activity restriction on 6-minute walking test performance in patients with chronic heart failure. *Am Heart J* 1997; **133**: 447–53.

28 Parkatti T, Wacker P, Andrews N. *Functional capacity from Nordic Walking among elderly people*. Finland, Seminar poster at University of Jyväskylä, 2002.

29 Jeollenbeck T, Leyser D, Classen C, Mull M, Grueneberg C. Biomechanical loading of the lower extremities during Nordic walking – a field study. *Paper presented at the International Symposium on Biomechanics in Sport*, Salzburg, 2006.

30 Kleindienst F, Stief F, Wedel F, Campe S, Krabbe B. Joint loading of lower extremities during Nordic walking compared to walking based on kinetic and kinematic data. *Paper presented at the International Symposium on Biomechanics in Sport*, Salzburg, 2006.

31 Hansen L, Henriksen M, Larsen P, Alkjaer T. Nordic Walking does not reduce the loading of the knee joint. *Scand J Med Sci Sport* 2008; **18**: 436–41.

32 Hagen M, Henning E, Stieldorf P. Ground reaction forces, rear foot motion and wrist acceleration in Nordic walking. *Paper presented at the International Symposium on Biomechanics in Sport*, Salzburg. 2006.

33 Collins E, Langbein W, Orebaugh C *et al*. Pole Striding exercise and vitamin E for management of peripheral vascular disease. *Med Sci Sports Exerc* 2003; **3**: 384–93.
34 Morso L, Hartvigsen J, Puggaard L, Manniche C. Nordic Walking and chronic low back pain: design of a randomized clinical trial. *Musculoskelet Disord* 2006; **7**: 77.
35 Strömbeck BE, Theander E, Jacobsson LT. Effects of exercise on aerobic capacity and fatigue in women with primary Sjogren's syndrome. *Rheumatology* 2007; **46**: 868–71.
36 Baatile J, Langbein W, Weaver F, Maloney C, Jost M. Effect of exercise on perceived quality of life in individuals with Parkinson's disease. *J Rehabil Res Dev* 2000; **37**: 529–34.
37 Kukkonen-Harjula K, Hiilloskorpi H, Manttari A *et al*. Self guided brisk walking training with or without poles: a randomized-controlled trial in middle-aged women. *Scand J Med Sci Sports* 2007; **17**: 316–23.
38 Karawan A. *The effects of twelve weeks of walking or Exerstriding on upper body muscular strength and endurance*. MSc thesis, University of Wisconsin – La Crosse, Wisconsin, USA, 1992.