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NORDIC WALKING – A NEW FORM OF ADAPTED PHYSICAL ACTIVITY (A LITERATURE REVIEW)

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ABSTRACT
Purpose. The purpose of this study was to analyze scientific evidence on the effects that Nordic Walking (NW) has on the human body. **Basic procedures.** A comprehensive search of computer databases (MEDLINE/PubMed, CINAHL, and SPORTDiscus) was conducted to identify relevant English and Polish studies on NW that were published from 1995 to 2009 and based on scientific research. **Main findings.** A total of 26 studies met the inclusion criteria. The majority of studies (12) discussed physiological issues, eleven studies were dedicated to NW as a form of rehabilitation (including one case study), and three studies focused on biomechanical issues present in NW. **Conclusions.** Not all of the widely promoted benefits of NW were confirmed in the results of the found scientific studies. Often analyzed issues did not provide sufficient explanation. There is a large discrepancy in the results of physiological responses during NW in a variety of conditions (on a treadmill with/without grade; field – uphill/downhill/horizontal level terrain). The results of studies analyzing the effects of NW training as a form of rehabilitation particularly in the areas of cardiology confirmed the positive aspects of including NW towards a patient's rehabilitation after acute coronary syndrome, with intermittent claudication, and after coronary artery disease, or after myocardial infarction. Contrary to popular belief and previously done studies, recent research has shown that NW does not reduce the loading of the knee joint.

Key words: review, Nordic Walking, adapted physical activity, physical activity

Introduction

Recently there has been a growing interest in Nordic Walking (NW), i.e. walking with poles similar to those used in cross-country skiing [1–3]. The popularity of NW should not be surprising as it is typical way of human locomotion and one of the most common forms of everyday physical activity [4, 5]. The undoubted advantage of NW is its natural and simple movement. In addition, it is an automated activity, which under normal conditions does not require a lot of concentration during its execution. Due to the popularity and attractiveness of NW, the possibility of using it as a form of exercise in various areas of sport, recreation, tourism and rehabilitation is increasingly becoming more popular. NW can be divided into three basic categories: *Health*, *Fitness* and *Sport*, which itself has numerous variants, e.g. an introduction to jogging or/and running (*Nordic Walking Running*), its application to rollerblading (*Nordic Walking Blading*), or on snowshoes (*Nordic Snowshoeing*) [1]. In popular literature such as health magazines, handbooks and web sites, NW is recommended for everybody – children, adolescents, adults, seniors, pregnant women and those after childbirth, as well as for people with different health problems (hypertension, atherosclerosis, arthritis, back pain, sciatica, osteoporosis, obesity, underweight, depression) [6–8]. Therefore, NW can be considered as a form of adapted physical activity recommended for different groups of people with special needs. The authors of such popular literature state, that among others, the NW can provide the following benefits: reinforcing of the immunological system, a reduction in cholesterol levels [6], an improvement in the blood supply, an increase in red blood cell count, a 30% reduction of joint stress, better mood [6, 7], the engagement of 70–90% of the body's muscles, a reduction in pulse rate while at rest, and a reduction of the load on knee joints [8]. It raises the question whether the beneficial effects of practicing NW, so widely touted, are in fact confirmed by scientific evidence?

Thus, the objective of this study was to analyze the available scientific literature on the effects of Nordic Walking on human body.

Material and method

The available Polish and foreign literature (only scientific journals) on NW published between 1995–2009 was analyzed. In searching for the available foreign lit-

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erature the following databases were used: the bibliographic database of the US National Library of Medicine (NLM) and National Institute of the Health (NIH) – MEDLINE/PubMed, SPORTDiscus and CINAHL databases. "Nordic Walking" and "walking poles" were the key terms used to find the articles. Only English language research papers were taken into consideration. This criteria were met by 23 items out of 122 found in the three databases: SPORTDiscus – 73, MEDLINE/PUBMed – 43 and CINAHL – 6 (after excluding those entries that appeared more than once in the databases). Polish literature was screened analyzing the content of the Central Library (BIBLO) database which includes Polish scientific literature in the field of sport, medicine, health and other related sciences. While searching BIBLO, the key term "Nordic Walking" was used. Only research papers were included in the analysis. There were three papers that met the inclusion criteria.

Results

A review of the literature indicates an increase in researchers' interest in Nordic Walking (3 manuscripts published in 1995–2000, 4 manuscripts in 2001–2005, 19 manuscripts in 2006–2009), however, in the available Polish literature only 3 manuscripts were found (tab. 1–3). Most of the studies (12) examined physiological issues in Nordic Walking [3, 9–19], ten papers were on the use of NW in rehabilitation [20–29] and three items concerned biomechanical aspects of NW [2, 30, 31]. One publication was a case study of NW used for treating of a sacral stress fracture that resulted from training overload [32].

Physiological changes during NW

In those studies which focused on physiological issues (Tab. 1), the authors analyze physiological indices in NW and those when walking without poles, or jogging executed on different conditions – in the field, or on a treadmill with different surfaces and inclinations. Church et al. [9] investigated walking with and without poles under field conditions. They noticed a significantly ($p < 0.001$) higher caloric expenditure when walking with poles (6.2 ± 1.7 kcal $\cdot$ min^{-1}) compared to walking without poles (5.2 ± 1.4 kcal $\cdot$ min^{-1}). Also the values of maximal oxygen uptake and heart rate were significantly higher ($p < 0.001$) when walking with poles (16.7 ± 3.6 ml $\cdot$ min^{-1} $\cdot$ kg^{-1}, 114 ± 15 beat min^{-1}, respectively) than when walking without poles (13.9 ± 2.7 ml $\cdot$ min^{-1} $\cdot$ kg^{-1}, 107 ± 13 beat min^{-1}, respectively). The authors showed there were higher energy cost (19%), maximal oxygen uptake (20%) and heart rate (6%) in NW than when walking under the field-testing conditions [9]. On the other hand, Knobloch [14] did not observe any differences in the hemodynamic parameters (heart rate, cardiac output, stroke volume) between NW and conventional brisk walking, without poles, in the field.

Some studies, which compared NW and walking without poles on a treadmill, reported no clear findings [17–19]. Porcari et al. [17] recorded an increase in oxygen cost even by 23% at a belt speed of 1.7 m $\cdot$ s^{-1} when comparing NW to walking without poles (24 ± 3.23 and 19.6 ± 3.08 ml $\cdot$ min^{-1} $\cdot$ kg^{-1}, $p < 0.05$, respectively). The values of energy expenditure and heart rate were also significantly higher ($p < 0.05$) during NW (8.4 ± 1.97 kcal $\cdot$ min^{-1}, 132 ± 16 beat min^{-1}, respectively) than when walking without poles (6.9 ± 1.78 kcal $\cdot$ min^{-1}, 114 ± 13 beat min^{-1}, respectively) [17]. Rodgers et al. [18] presented a higher oxygen consumption, by 12%, when NW ($20.5 \pm 1,2$ ml $\cdot$ min^{-1} $\cdot$ kg^{-1}) was compared to walking without poles (18.3 ± 2.5 ml $\cdot$ min^{-1} $\cdot$ kg^{-1}) on a treadmill moving at a speed of 1.8 m $\cdot$ s^{-1}. Similarly, the results of research found by Porcari et al. [17] indicated significantly higher ($p < 0.05$) values of energy cost and heart rate in NW (173.7 ± 20.9 kcal, 132 ± 19 beat min^{-1}, respectively) than when walking without poles (140.7 ± 27.2 kcal, 121 ± 21 beat min^{-1}, respectively) [18]. Schiffer et al. [19] identified an 8% increase in maximal oxygen uptake at a treadmill speed of 1.8 m $\cdot$ s^{-1} when NW was compared to walking without poles ($p < 0.05$). These findings are in accordance with Rodgers' et al. [18] results, however, they are different from those reported by Porcari et al. [17].

In research performed on the impact of terrain inclination on maximal oxygen uptake in NW, Perrey et al. [16] showed a significant ($p < 0.05$) increase in maximal oxygen uptake (19%) when walking downhill (an inclination angle of 15%, i.e. about 8.5°) with poles compared to walking downhill without poles. Hansen and Smith [11] analyzed energy expenditure when walking without poles, both with standard poles and with poles 7.5 cm shorter, during uphill, downhill (an inclination angle of 12°) and horizontal level walking. The authors noted significantly higher energy expenditure during uphill, downhill and horizontal level walking with standard poles (10.9 ± 0.5, 5.3 ± 0.4, 8 ± 0.7 MET, respectively) when compared to walking without poles (10 ± 0.4, 3.5 ± 0.1, 4.8 ± 0.3 MET, respectively) [11]. Schiffer et al. [3] investigated the effects of three different surface conditions on energy cost during NW and reported significantly ($p < 0.05$) higher maximal oxygen uptake and energy cost (MET) in NW executed at a speed of 2.2 m $\cdot$ s^{-1} on the grass (36.1 ± 4.2 ml $\cdot$ min^{-1} $\cdot$ kg^{-1},

Table 1. Physiological changes in NW – a literature review compilation

Author	Year	*n*	Gender (F/M)	Age (years)	Aim of research	Measurements
Church et al. [9]	2002	22	11F/11M	27 ± 6(F), 34 ± 9(M)	A comparison of energy expenditures when walking under the field conditions with and without poles.	▪ HR ▪ indirect calorimetery
Hagner et al. [10]	2009	168	F	30–73	The effects of a 12-week NW program on basic indices characterizing premenopausal, perimenopausal, and postmenopausal women.	▪ HR ▪ indirect assessment of VO$_2$max ▪ lipid profile ▪ total fat mass ▪ waist circumference ▪ body mass index
Hansen et al. [11]	2009	12	11F/1M	50 ± 2	The effects of poles' length on energy cost during uphill, downhill and horizontal NW.	▪ HR ▪ indirect calorimetery ▪ self assessment of comfort
Jürimäe et al. [12]	2009	28	F	21 ± 2	The effects of NW intensity on physiological responses of young women of different aerobic capacity levels.	▪ HR ▪ direct assessment of VO$_2$max ▪ ratings of perceived exertion
Kamień [13]	2008	72	64F/8M	19–73	An assessment of endurance levels in people participating in a 8-week NW training program.	▪ 2 km walk test ▪ Physical Fitness Index
Knobloch [14]	2009	48	*	51 ± 11	The effects of NW and walking in the field on hemodynamic parameters.	▪ HR ▪ hemodynamic parameters ▪ perceived level of exertion
Kukkonen-Harjula et al. [15]	2007	106	F	54 ± 3	The effects of a 3-month NW program (with poles) and walking without poles on women's cardiorespiratory and neuromuscular fitness.	▪ HR ▪ LA$_{max}$ ▪ direct assessment of VO$_2$max ▪ health related fitness tests (HRF)
Perrey et al. [16]	2008	12	7F/5M	28 ± 9	The effects of NW and walking on physiological and kinematic indices with respect to different terrain inclinations.	▪ HR ▪ direct assessment of VO$_2$max ▪ indirect calorimetery ▪ ratings of perceived exertion
Porcari et al. [17]	1997	32	16F/16M	24 ± 3(F), 23 ± 3(M)	The effects of using poles when walking on women's and men' physiological responses during a maximal treadmill test.	▪ HR ▪ direct assessment of VO$_2$max ▪ ratings of perceived exertion
Rodgers et al. [18]	1995	10	F	24 ± 4	A comparison of energy expenditures and physiological responses when walking with and without poles.	▪ HR ▪ direct assessment of VO$_2$max ▪ indirect calorimetery ▪ ratings of perceived exertion
Schiffer et al. [19]	2006	15	F	44 ± 6	A comparison of physiological responses during a gradually increasing intensity of NW, walking and jogging.	▪ HR ▪ direct assessment of VO$_2$max ▪ LA$_{max}$
Schiffer et al. [3]	2009	13	F	26 ± 4	The effects of different surfaces on energy expenditure during NW.	▪ HR ▪ direct assessment of VO$_2$max ▪ LA$_{max}$ ▪ forces acting on the poles during ground contact

F – female, M – male, NW – Nordic Walking, HR – heart rate,
VO$_2$max – maximal oxygen uptake, LA$_{max}$ – maximal lactate concentration in the blood

* no data

10.2 ± 1.2 MET, respectively) than on concrete surface (32.1 ± 2.5 ml · min^{-1} · kg^{-1}, 9.1 ± 0.7 MET, respectively). Jürimäe et al. [12] have tried to determine the influence of NW intensity (slow walking, usual walking speed, faster walking speed, maximal walking speed) on the physiological reactions of women having different aerobic capacity – group 1 (maximal oxygen uptake > 46 ml · min^{-1} · kg^{-1}, $n = 8$), group 2 (maximal oxygen uptake 41–46 ml · min^{-1} · kg^{-1}, $n = 12$), and group 3 (maximal oxygen uptake < 41 ml · min^{-1} · kg^{-1}, $n = 8$). No significant differences emerged between the three groups in their physiological responses during NW of various intensity [12].

Recently, some studies [10, 13, 15] have examined the effects of a NW training. Hagner et al. [10] assessed the effects of a 12-week NW programme on the basic indices characterizing female health in premenopause, perimenopause and postmenopause. The results revealed a significant ($p \leq 0.05$) increase in maximal oxygen uptake and high density lipoprotein (HDL), as well as a significant ($p \leq 0.05$) reduction in: total cholesterol level, low density lipoprotein (LDL), triglycerides, body mass index (BMI) and waist circumference in the three groups [10]. Kamień [13] presented the influence of a 8-week NW training programme on the performance of a 2 km walk test executed with poles and without poles in three groups – group 1: women who practice NW, aged 50 ± 12 years ($n = 32$) and 21 ± 1 ($n = 17$); group 2: women who walk without poles, aged 20 ± 1 ($n = 15$), group 3: men who practice NW, aged 52 ± 12 years ($n = 8$). The author suggests that the acquisition of a good NW technique may cause an improvement in the results obtained on a given distance without any visible increase on the physiological cost [13]. Kukkonen-Harjula et al. [15] did not notice any significant differences in maximal oxygen uptake between women who walked for 13 weeks with and without poles. Both training programmes similarly improved maximal oxygen uptake [15].

NW in the rehabilitation process

Due to attractiveness and popularity of NW, its application towards rehabilitation are increasingly considered [1]. Previous studies (Tab. 2) have mostly explored the effectiveness of NW in cardiac rehabilitation programmes for individuals after an acute coronary syndrome [21, 22], with intermittent claudication [23], with coronary artery disease [28] and after myocardial infraction [29]. Kocur et al. [21] analyzed the exercise capacity and physical fitness between three groups of patients who had just begun their rehabilitation after an acute coronary syndrome, i.e. a 3-week inpatient cardiac rehabilitation programme. A control group ($n = 20$, average age 54.5 ± 9.4 years) took part in a standard rehabilitation programme based on endurance training on a cycle ergometer and by doing calisthenics; the NW group ($n = 40$, average age 51.4 ± 6.3 years) participated in a standard rehabilitation programme and in NW training, whereas a walking group ($n = 20$, average age 51.3 ± 7.1 years), apart from doing the standard rehabilitation programme, participated in supervised traditional walking training. After the 3-week rehabilitation programme the NW group had a higher exercise capacity measured by a symptom-limited treadmill exercise test following the modified Bruce protocol (expressed in metabolic equivalents, METs) compared to the control group (10.8 ± 1.8 and 9.2 ± 2.2 MET, respectively; $p = 0.025$). Also, physical fitness, assessed by a Fullerton Functional Fitness Test, improved in the NW group and walking group, in contrast to the control group (except the 6-minute walk test). The authors concluded that NW can be used as a supplement to standard short-term rehabilitation in men after acute coronary syndrome, because it may enhance their coordination and exercise capacity [21].

In another study the same authors [22] compared the estimation methods of energy expenditure in patients after an acute coronary syndrome during NW, general fitness exercises and cycle ergometer training. Three estimation methods of energy expenditure (with the use of a heart rate monitor, an accelerometer and on the basis of heart rate calculated from mean exercise heart rate value based on the data from the treadmill exercise test) were examined during three forms of training used in cardiac rehabilitation – 20-minute cycle ergometer training, 30-minutes of NW and a 30-minute general fitness exercises. During NW, in patients after an acute coronary syndrome, no significant differences were observed between the energy expenditure indicated by a heart rate monitor (255.48 ± 103.5 kcal) and the energy expenditure calculated in relation to the exercise test results (262.10 ± 78.9 kcal), while the energy expenditure calculated in relation to the exercise test significantly ($p = 0.001$) differed from the energy expenditure assessed by accelerometer (227.78 ± 48.6 kcal). NW was characterized by the highest total energy expenditure (5–6 MET) of all the forms of training used in cardiac rehabilitation and examined in the study. The authors underline that applying NW (a 2.5 km walk with poles interrupted by a 5-minute active rest halfway through) as a supplementary activity to the standard rehabilitation programme (general fitness exercises and cycle ergometer training) may help to meet the minimal caloric load requirement of training (350–600 kcal for a daily train-

Table 2. NW in the rehabilitation process – a literature review compilation

Author	Year	*n*	Gender (F/M)	Age (years)	Aim of research	Measurements
Allet et al. [20]	2009	25	*	68 ± 9	The effects of various walking aids on walking capacity, gait parameters and satisfaction in patients with poststroke hemiparesis.	▪ temporo-spatial gait parameters ▪ 6-minute walk test ▪ perceived satisfaction
Kocur et al. [21]	2009	80	M		The effects of a 3-week NW training in the early rehabilitation stage of exercise capacities and physical fitness of patients after an acute coronary syndrome.	▪ HR ▪ exercise trial ▪ indirect calorimetery ▪ Fullerton Functional Fitness Test ▪ ratings of perceived exertion
Kocur et al. [22]	2009	40	M	51 ± 6	The comparison of the estimation methods of energy expenditure during NW, general fitness exercises and cycle ergometer training in patients after an acute coronary syndrome.	▪ HR ▪ indirect calorimetery
Oakley et al. [23]	2008	21	M	57–79	The effects of NW on walking distance and cardiopulmonary workload in patients with intermittent claudication.	▪ HR ▪ walking distance ▪ direct assessment of VO_2max ▪ ratings of perceived exertion and pain
Sprod et al. [24]	2005	12	F	*	The effects of a 8-week program of walking with poles on female after breast cancer.	▪ range of motion in the shoulder joint ▪ endurance tests of upper-body strength
Strömbeck et al. [25]	2007	21	F	41–65	The effects of a 12-week NW program on aerobic capacity, perceived fatigue, mood and quality of life in patients with primary Sjögren's syndrome.	▪ indirect assessment of VO_2max ▪ ratings of perceived exertion ▪ health related quality of life ▪ perceived fatigue ▪ depression and anxiety
Suija et al. [26]	2009	21	19F/2M	26–78	The effects of regular NW training on physical fitness and mood of patients with depression.	▪ HR ▪ 2 km walk test ▪ quality of life ▪ perceived mood
van Eijkeren et al. [27]	2008	19	M	58–76	An assessment of short-term and long-term effects of a 6-week NW program on fitness and quality of life of patients with Parkinson's disease.	▪ 10-meter walking speed test ▪ 6-minute walking test ▪ get-up-and-go-test ▪ quality of life
Walter et al. [28]	1996	14	M	62 ± 2	A comparison of the safety and effectiveness of walking with and without poles in cardiac patients with coronary artery disease in phase III/IV of cardiac rehabilitation.	▪ HR ▪ direct assessment of VO_2max ▪ ratings of perceived exertion ▪ electrocardiogram
Wilk et al. [29]	2005	30	*	40–66	The effects of NW on the improvement of exercise tolerance and physical performance in patients rehabilitated after a myocardial infarction	▪ HR ▪ exercise trial ▪ Fullerton Functional Fitness Test ▪ 6-minute walking test

F – female, M – male, NW – Nordic Walking, HR – heart rate, VO_2max – maximal oxygen uptake * no data

ing session) established for the prevention of secondary cardiovascular disease [22].

Oakley et al. [23] proved that men aged 57–79 with intermittent claudication can cover a significantly ($p \leq 0.001$) longer distance both without pain (130 m) and with pain (285 m) while walking with poles compared to walking without poles (77 m, 206 m, respectively). Moreover, at the maximal walking distance, patients experienced significantly ($p = 0.002$) less pain when using poles, assessed subjectively on a 10 point Borg scale (Borg CR-10), than when walking without poles (4.3 ± 0.5; 5.6 ± 0.5, respectively). Significantly higher maximal oxygen uptake when walking with poles was observed both without feeling pain ($1.12 \pm 0.08\ l \cdot min^{-1}$) and with pain ($1.20 \pm 0.05\ l \cdot min^{-1}$) compared to walking without poles ($0.95 \pm 0.06\ l \cdot min^{-1}$, $1.03 \pm 0.06\ l \cdot min^{-1}$, respectively). While walking those patients feeling pain evaluated their perceived exertion similarly on a Borg 20-point scale. The research findings imply that NW allows patients with intermittent claudication to increase the distance they can walk due to pain relief in their legs, despite higher cardiopulmonary work at maximal walking distance. It means that NW could become a useful exercise for improving cardiopulmonary fitness in this group of patients [23].

Similar results were obtained by Walter et al. [28] in men with coronary disease aged 48–71 years. Maximal oxygen uptake was significantly ($p \leq 0.05$) higher when walking with poles ($1.60 \pm 0.18\ \mathrm{l} \cdot \mathrm{min}^{-1}$) than when walking without poles ($1.30 \pm 0.18\ \mathrm{l} \cdot \mathrm{min}^{-1}$). Another important aspect of this study was a lack of disturbances in patients' ECG during the two walking variants which may indicate that NW can be a safe and effective method at increasing the walking intensity in the selected III/IV phase of cardiac rehabilitation in patients with coronary disease [28].

NW's influence on exercise tolerance and physical performance in patients after a myocardial infarction was examined by Wilk et al. [29]. The authors found significant ($p \leq 0.05$) effects of NW training on exercise tolerance, which was 7.9 ± 1.8 MET before the training sessions started and reached 10.3 ± 2.3 MET after 15 sessions of NW. Although a significant improvement was observed in the group without poles (14%), the percentage in the NW group was higher – 30%. In the Fullerton Functional Fitness Test both groups showed significant ($p \leq 0.05$) improvements in all variables except in tests measuring upper-body strength and coordination [29]. Similar effects of NW and walking without poles on the physical fitness of patients after an acute coronary syndrome was presented by Kocur et al. [21].

Two studies have investigated the application of NW as a form of neurological rehabilitation in patients after a cerebral stroke [20] and Parkinson's disease [27]. Allet et al. [20] analyzed the effects of three different walking aids (a simple cane with an ergonomic handgrip, a 4-point cane and a NW pole) on walking capacity and patient satisfaction with poststroke hemiparesis. Research indicated that the distance covered in a 6-minute walk test was significantly longer with the help of a simple cane with an ergonomic handgrip ($p = 0.008$) compared to a NW pole. No significant differences were observed among the three walking aids in the following temporo-spatial gait parameters: velocity, cadence, step time difference and step length difference. Patients with poststroke hemiparesis found the walking with a NW pole significantly less beneficial (in terms of subjective satisfaction) than when walking with a 4-point cane ($p = 0.002$) and a simple cane with an ergonomic handgrip ($p = 0.001$). In addition, it is not recommend to use NW poles in the rehabilitation of patients after a stroke [20]. Van Eijkeren et al. [27] demonstrated that after a 6-week NW training programme men with Parkinson's disease (Hoehn and Yahr scale stage range 1–3) may enhance both their physical fitness and quality of life. Significant ($p \leq 0.01$) improvements were noted: in the time length during a get-up-and-go-test and a 10-meter walking speed test, in the distance covered during a 6-minute walking test, and in the subjective evaluation of quality of life measured by a PDQ-39[1] questionnaire. What is very important, the benefits of training continued on after 5 months [27].

Sprod et al. [24] assessed the effects of an 8-week NW training programme on the shoulder function in female breast cancer survivors. An experimental group which used walking poles during aerobic training achieved significantly higher results in muscular endurance as measured by the bench press ($p = 0.046$) and latissimus dorsi pull down ($p = 0.013$) when compared to the control group. The authors suggest that NW can be a valid and attractive form of physical activity in this group of female patients, where the conditioning of the upper-body seems apparent [24].

The influence of a 12-week NW training programme on aerobic capacity, the perceived feeling of fatigue, mood and quality of life in patients with primary Sjögren's syndrome, aged 41–65 years was studied by Strömbeck et al. [25]. The authors presented significantly better results of the experimental group than the control one in: aerobic capacity measured by the Astrand test ($p = 0.03$), perceived feeling of fatigue rated on a VAS[2] scale ($p = 0.03$), the perceived exertion evaluated by the Borg Scale[3] ($p = 0.03$) and depression assessed by the Hospital Anxiety and Depression Scale (HADS) ($p = 0.02$). No differences were observed in the health related quality of life (HRQoL) and anxiety (HADS) of the two groups. However, a significant improvement in the quality of life related to the patient's health status, evaluated by the SF-36[4] in the categories of physical fitness ($p = 0.01$) and mental health ($p = 0.03$), was noticed in participants from the training group. The authors suggest that NW should be a part of the rehabilitation process for patients with primary Sjögren's syndrome [25].

Suija et al. [26] investigated the effects of regular NW training on physical fitness, the quality of life and

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[1] Parkinson's Disease Questionnaire-39.

[2] Visual Analogue Scale.

[3] Ratings of Perceived Exertion (RPE).

[4] Short Form Health Survey 36.

mood in patients suffering from depression. Physical fitness was calculated by taking into account the time needed to walk a distance of 2 km (in minutes and seconds), the heart rate at the end of the walk, age (in years) and body mass index. Although an improvement in physical fitness was observed – it increased from 21.99 ± 20.38 to 37.80 ± 12.05 – due to the large variability of the results (high standard deviations) the difference was not significant. Initially, as based on the Composite International Diagnostic Interview (CIDI), depression symptoms were diagnosed in 16 persons (7 – mild, 5 – moderate, 4 – severe), whereas after the 24-week NW training programme depression symptoms were noticed in only 7 persons (5 – mild, 2 – severe). The findings of this study showed that regular NW could be used as a form of rehabilitation for depressed patients [26].

Knobloch et al. [32] presented an example of applying NW in the treatment of a sacral stress fracture caused by training overload in a 22-year-old female long-distance runner. After 2 weeks of complete physical inactivity the subject underwent moderate physical activity (stationary bicycle) for 60–90 minutes per day. After another 2 weeks, a 60–90 minute session of NW was included per day. Seven weeks after the sacral stress fracture was diagnosed the subject was able to run about 90 km per week without feeling pain. Based on the results, the authors recommend including NW in the treatment programme of sacral stress fractures caused by training overload as a physical activity of low intensity suitable for athletes.

The biomechanical aspects of NW

In studies which focused on biomechanical issues, [2, 30, 31] the authors analyzed the loadings of joints during NW (Tab. 3). Hansen et al. [2] made a three-dimensional gait analysis with and without poles. The authors calculated internal flexor and extensor joint moments around the ankle, knee and hip and measured both the internal compression and shear forces for the joints as well as the external ground reaction forces during NW and when walking without poles. No significant differences were observed in the compression or shear force acting on the knee joint during NW when compared to walking without poles. The peak knee flexion in the first half of the stance phase was significantly ($p = 0.02$) larger during NW (–32.5 ± 6.0°) than when walking without poles (–28.2 ± 4.2°), which may suggest a more "bouncy" walk in NW when compared to normal walking. The hip's range of motion was significantly ($p = 0.01$) increased during NW (64.4 ± 10.2°) when compared with walking without poles (57.8 ± 9.7°). Changes in the knee and hip joint angles were not followed by changes in joint dynamics [2]. Stief et al. [30] have tried to quantify any differences in joint loadings of the lower extremities among walking, NW and running using a three-dimensional kinematic analysis and force platform. The authors demonstrated that the higher knee extension moment in NW when compared with walking can be explained by the longer steps and the higher sole angle during the first part of the stance phase. In the transverse plane the ankle moments were significantly greater in NW (–16.49 ± 6.21 Nm) than in walking (–15.37 ± 5.84 Nm, $p = 0.03$) and running (–7.94 ± 3.9 Nm, $p = 0.001$) [30]. Another group of investigators [31] analyzed the kinetic variables when walking with and without poles. Willson et al. [31] showed that during NW such indices as walking speed (1.59 ± 0.20 $\mathrm{m \cdot s^{-1}}$), stride length (1.77 ± 0.2 m) and stance (0.66 ± 0.02 s) were significantly higher ($p < 0.008$) than in walking without poles (1.48 ± 0.18 $\mathrm{m \cdot s^{-1}}$, 1.57 ± 0.12 m, 0.65 ± 0.02 s, respectively). Another significant difference ($p < 0.008$) was a decrease in the vertical ground reaction force (Fz) during NW (372.39 ± 62.47 N) when compared to walking without poles (388.32 ± 81.97 N). Also, the vertical (compressive) knee joint reaction force when walking with poles was significantly ($p < 0.01$) lower, by 4.1% in the poles back condition and by 4.4% in the poles front condition, than when walking without poles, what causes a reduction in the loading of the knee joints when walking with poles when compared to walking without poles [31].

Discussion

It is worth noting that not all beneficial effects of NW, so widely promoted, have been confirmed by the research findings and the issues that undrewent scientific analysis have not always found clear explanations. There is a large discrepancy among the comparative results of maximal oxygen uptake during NW and when walking without poles on a treadmill [17–19]. Rodgers et al. [18] noticed that during NW, maximal oxygen uptake increased by 12% at a belt speed of 1.8 $\mathrm{m \cdot s^{-1}}$, with Porcari et al. [17] – the increase amounted to 23% at a belt speed of 1.7 $\mathrm{m \cdot s^{-1}}$, while Schiffer et al. [19] recorded an increase by only 8% at a belt speed of 1.8 $\mathrm{m \cdot s^{-1}}$. A similar discrepancy can be observed between the results of heart rate measurements during NW and when walking without poles on a treadmill [17, 18], where the values are higher by 9–16%, whereas in the field [9] the heart rate is higher during NW by 6% when compared to walking without poles. However, it is important to underline that all the authors showed an

Table 3. Biomechanical aspects of NW – a literature review compilation

Author	Year	*n*	Gender (F/M)	Age (years)	Aim of research	Measurements
Hansen et al. [2]	2008	7	F	42–58	A comparison of the load on the knee, hip and ankle joints during NW and walking without poles.	▪ three-dimensional kinematic gait analysis
Stief et al. [30]	2008	15	M	31 ± 5	A comparison of the loadings of lower extremities joints during NW, walking and running.	▪ three-dimensional kinematic gait analysis
Willson et al. [31]	2001	13	5F/8M	30 ± 5	The efects of walking poles on lower extremity gait mechanics in healthy people	▪ three-dimensional kinematic gait analysis

F – female, M – male, NW – Nordic Walking

increase in maximal oxygen uptake and heart rate during NW both on the treadmill [17–19] and in the field [9], which may indicate that more intense work is performed during this form of physical activity when compared to walking without poles.

Research on the effects of terrain inclination on energy cost and maximal oxygen uptake during NW demonstrate an increase in oxygen uptake by 19% when walking downhill [16] and a higher energy expenditure when walking uphill (by 9%) and downhill (by 51%) [11] compared to walking downhill and uphill without poles. It was observed that the type of surface had influence on examined physiological indices during NW – on grass the energy cost was higher by 12%, and maximal oxygen uptake by 12.5% when compared to a concrete surface [3].

In two studies it was shown that regular NW training (8–13 weeks) in women leads to an increase in high density lipoprotein, a reduction in total cholesterol, low density lipoprotein, triacylglycerols and BMI [10], as well as an increase in maximal oxygen uptake [15], although no significant differences were noticed in the analyzed biomechanical and physiological indices between NW and walking without poles. It may prove that both NW and walking without poles have similar long term effects on the female body.

All of authors dealing with rehabilitation issues [20–29] underline the necessity of doing additional research. However, it seems that current scientific evidence, especially in the areas of cardiology [21–23, 28, 29], confirm the usefulness of NW in the rehabilitation programmes of patients after acute coronary syndrome, with intermittent claudication, with coronary artery disease, and after myocardial infarction. What seems particularly valuable is the possibility of continuing NW by cardiac patients on their own in the prevention of secondary cardiovascular disease.

Contrary to popular belief and the study by Willson et al. [31], recent research has indicated [2, 30] that NW does not reduce the load on the knee joint more than walking without poles. Moreover, Stief et al. [30] demonstrated an increase of the load on the ankle joints during NW when compared to walking without poles or running. Taking into consideration the discrepancies in the research findings, further studies are neccesary in trying to answer if NW reduces the loading of lower extremities joints.

Conclusions

The recent promotion of NW resulted in an increase in researchers' interest in this form of physical activity in different groups of people with special needs. However, the research results have so far not explained unequivocally the beneficial effects, so widely promoted, of NW. Thus, further investigation is needed to explain if NW does in fact reinforce the immunological system, increases the number of red blood cells, reduce joint stress by 30%, raises well-being, provides 70–90% of body muscle movement or reduces load on knee joints.

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