**Nordic Walking for Individuals with Cardiovascular Disease:**

**A Systematic Review and Meta-analysis of Randomized Controlled Trials**

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**Abstract**

**Background:** Exercise is the cornerstone of rehabilitation programs for individuals with cardiovascular disease (IwCVD). Although conventional cardiovascular rehabilitation (CCVR) programs have significant advantages, non-conventional activities such as Nordic walking (NW) may offer additional health benefits. Our aim was to appraise research evidence on the effects of NW for IwCVD.

**Design:** Systematic review and meta-analysis.

**Methods:** A literature search of clinical databases (PubMed, MEDLINE, Scopus, Web of Science, Cochrane) was conducted to identify any randomized controlled trials (RCTs), including: *(i)* IwCVD *(ii)* analyses of the main outcomes arising from NW programs. Data from the common outcomes were extracted and pooled in the meta-analysis. Standardized mean differences (SMD) were calculated and pooled by random effects models.

**Results:** Fifteen RCTs were included and eight trials entered this meta-analysis. Studies focused on coronary artery disease (CAD), peripheral arterial disease (PAD), heart failure (HF) and stroke. In CAD, significant differences between NW+CCVR and CCVR were found in exercise capacity (SMD:0.49; *p*=0.03) and dynamic balance (SMD:0.55; *p*=0.01) favoring NW+CCVR. In PAD, larger changes in exercise duration (SMD:0.93; *p*<0.0001) and oxygen uptake (SMD:0.64; *p*=0.002) were observed following NW compared to controls. In HF, no significant differences were found between NW and CCVR or usual care for peak VO2 and functional mobility. In post-stroke survivors, functional mobility was significantly higher following treadmill programs with poles rather than without (SMD:0.80; *p*=0.03).

**Conclusions:** These data portray NW as a feasible and promising activity for IwCVD. Further studies are necessary to verify whether NW may be incorporated within CCVR for IwCVD.

**Abstract word count:** 250

**Key words:** Nordic Walking; Polestriding; Cardiovascular Disease; Exercise Capacity.

**Introduction**

Regular exercise is beneficial to cardiovascular (CV) health and longevity (1). The American College of Sports Medicine (ACSM) and the Center for Disease Control and Prevention recommend at least 30 minutes of moderate-intensity physical activity on most days of the week (1, 2). It is well established that physical activity at and above these levels may decrease mortality by up to 27% (3). Despite these recommendations, sedentary behavior in developed countries is on the rise and contributes to the increase in CV mortality (2, 3), thus justifying the growing attention towards exercise-based CV rehabilitation programs for secondary prevention (4). These programs play a key role in improving the overall health status and quality of life (QOL) of participants by modifying CV risk factors, particularly sedentary behavior (5, 6). The efficacy of exercise-based programs relies heavily on patient adherence, leading to a wide range of methods being attempted to increase participation and compliance (4-7). These include group activities that are both physically and socially engaging, which promote patient involvement. Nordic walking (NW) is one such activity. NW has its origins in Finland where it was introduced in the late ‘80s as a summer training for Nordic skiing. After 2000, it was spread out worldwide and increasingly investigated, soon becoming an exercise component of the CV rehabilitation programs (8, 9).

NW is a particular form of physical activity similar to Nordic skiing and combines active use of the trunk and upper limbs with classic walking, using specifically designed poles. The result is a full-body workout that combines the ease and accessibility of conventional walking with upper body conditioning, so that higher energy expenditure can be achieved (10).

Previous studies have shown that NW enhances aerobic capacity, muscular strength, balance and the overall well-being of healthy subjects (8). Additionally, NW is effective in positively modifying traditional CV risk factors such as hypertension, diabetes mellitus, and dyslipidemia (8, 9).

Physical training in conventional cardiovascular rehabilitation (CCVR) programs generally consists of aerobic training on a treadmill or cycle ergometer, often complemented by muscle strengthening exercises and calisthenics (5, 6). NW has been proposed as a complementary tool to these programs, due to the additional engagement of the upper body (resulting in the involvement of approximately 70-90% of the body’s skeletal musculature), and the relatively higher energy expenditure compared to traditional walking (TW) by an estimated 8% (10). In addition, the employment of the poles reduces loading stress at the knee joint by approximately 30% compared to walking without poles (11). These characteristics support NW as a promising form of physical activity in individuals with CV disease (IwCVD), especially the elderly and those with multiple comorbidities (8, 9).

The aims of this systematic review and meta-analysis were: *(i)* to appraise the available evidence on the health effects and clinical relevance of NW in individuals with established CVD and, *(ii)* to determine a precise estimate of NW-induced changes on primary outcomes such as those cardiovascular and functional (*i.e.*, exercise capacity, maximal oxygen consumption, exercise duration), and on secondary outcomes (*i.e.,* QOL, non-motor symptoms) in individuals diagnosed with CVD (12).

**Methods**

*Protocol registration and literature search*

The systematic review protocol was registered in Figshare.com on October 2016 with the following digital object identifier: [doi.org/10.6084/m9.figshare.3988974.v1](https://doi.org/10.6084/m9.figshare.3988974.v1).

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and flow chart diagram were used as a reporting structure for this systematic review (13, 14).

We conducted electronic searches of citation databases from inception to November 2016. PubMed medical databases including MEDLINE, Scopus, Web of Science and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched. A comprehensive search strategy for primary studies, developed and performed by two of the authors (L.C. and P.P.B.), used the text word terms: “Nordic Walking” OR “Polestriding” OR “Walking Poles”. Only randomized controlled trials (RCTs) in English (15) were selected and the references of all included articles were further checked for relevant publications. A detailed literature search strategy for each of the databases can be found in Supplementary file 1.

*Eligibility criteria and search strategy*

The articles included in this systematic review and meta-analysis had to meet the following inclusion criteria based on the PICO model (14, 16): *(i)* studies enrolling individuals with established CVD (12); *(ii)* studies employing a mid to long-term (defined as ≥ 2 weeks) NW program. Titles and abstracts of potentially relevant articles were independently assessed by two of the authors (L.C. and P.P.B.) and duplicates were removed. A full-text article was evaluated when the title or abstract presented insufficient information to determine inclusion. In cases of disagreement, a mutual discussion to reach consensus was carried out and, if necessary, a third author (A.M.) contributed to the final decision.

*Data extraction and quality assessment*

Demographic characteristics of the samples (average age, gender and CVD area), trial methodologies and interventions (control groups or other comparative groups, NW program characteristics and duration), and the primary (cardiovascular and functional outcomes), and secondary study outcomes (QOL and non-motor-symptoms) of each trial were collected independently by the two authors (L.C. and P.P.B.) using a standardized data extraction form.

Subsequently, the quality and risk of bias assessments were completed by employing the Physiotherapy Evidence Database (PEDro) scale (17). The PEDro scale is based on the Delphi list developed by Verhagen and colleagues (1998) to assess the methodological quality of RCTs in physical therapy. This scale consists of 11 items rating the internal validity (10 items) and external validity (1 item) of clinical trials, with the total score ranging from 1 to 10 points (a higher score corresponds to a higher methodological study quality) (17). As above, in cases of disagreement, a third author (A.M.) made the final decision.

*Statistical analysis*

The clinical relevance of the intervention-induced changes reported as significant was estimated by calculating the Hedges *g* effect size (ES: small ≤ 0.5; moderate 0.51-0.79; large ≥ 0.8), according to the formulae by Hedges and Olkin (18, 19). Absolute ES were calculated for each study by comparing at the post-intervention NW *versus* other interventions and/or controls (*i.e.*, NW *versus* CCVR, NW *versus* non-active control group, NW *versus* traditional walking and NW *versus* treadmill training).

A meta-analysis was planned if at least two studies reported data for the same outcome measure (13). Heterogeneity across the studies was calculated using the Q-test (Chi-square) and the inconsistency I2 statistic (20). An I2 with a value > 50% was considered indicative of high heterogeneity. All meta-analyses were performed using RevMan 5.3 (Review Manager, the Cochrane Collaboration). Raw data (means and standard deviation, SD) were extracted or calculated from standard errors, 95% confidence intervals (CI), *P* values, t values, or F values. In case of missing data a formal request was sent to the corresponding and first authors of each study. Publication bias was assessed by funnel plot symmetry and Egger regression intercept. Pooling of data was carried out using a random rather than a fixed-effects model since many investigators consider it more appropriate in the context of medical decision-making (21). In order to allow interpretation of the pooled estimate of the effects obtained, the Standardized Mean Difference (SMD), which expresses the intervention effect in standard units rather than the original units of measurement, was reported. According to Cohen (22), an SMD of 0.2 was considered as low, 0.5 as medium and 0.8 as large.

Lastly, in case of studies originating from the same dataset, the sample was counted once to avoid sample size inflations.

**Results**

*Study selection*

The comprehensive flow chart for the study selection process is presented in Figure 1.

Fifteen RCTs, focusing on NW as a form of rehabilitation for IwCVD, met all the eligibility criteria and were included in the qualitative synthesis of this review (23-37). A detailed overview of the excluded studies and the main reasons for exclusion can be found in Supplementary file 2.

Of the 15 studies analyzed, 8 trials showing sufficient homogeneity in the pre-defined comparisons (13) were included in the quantitative meta-analysis (23-25, 27, 32, 33, 36, 37) (Figure 1).

***Figure 1 - PRISMA flow diagram for selection of studies***

*Quality assessment*

The PEDro scale score ranged from 3 to 6 (mean 4.8 ± 0.9, median 5 ± 0.2) out of a maximum score of 10 (23-37). This was predominantly due to lack of blinding in all included studies. In addition, adequate follow-up outcomes were reported in only 6 out of the 15 studies (25-27, 29, 33, 36). For all included studies, the results of between-group statistical comparison were reported, and point estimates and measures of variability were provided for at least one key outcome. Study and control/comparison groups were also similar at baseline in all of the included studies but one (32). Four studies performed an intention-to-treat analysis (28, 29, 32, 35), and allocation was concealed in only one study. Participants were randomized in all of the studies but one (31). The quality assessment of the included studies is reported in Supplementary file 3.

*Qualitative data synthesis*

The 15 selected studies were conducted between 2002 and 2016 and enrolled a total of 766 individuals, comprising 649 men (85%) and 87 women (11%). In one study (30 subjects) gender data were not available (23), whereas in 7 trials, participants' mean age was not clearly stated (24, 25, 33-37). Subjects ranged in age from 40 to 80 years old.

Among the 15 RCTs selected, 2 focused on coronary artery disease (CAD) (23, 24), 7 on peripheral arterial disease (PAD) (25-31), 4 on individuals with heart failure (HF) (32-35) and 2 on post-stroke survivors (36, 37).

All studies analyzed mid to long-term effects of NW training (from 3 to 24 weeks) performed as a standalone approach (25, 27-37), or in combination with CCVR programs (*i.e.,* aerobic training on a treadmill or cycle ergometer, complemented by muscle strengthening exercises and calisthenics) (23, 25) or compared to other interventions, such as integration with Vitamin E or placebo (26). Nine studies compared NW training to CCVR programs (23, 24, 30, 32) or to control groups (usual medical therapy and normal activities of daily living without prescribed exercise) and usual care (UC, recommendations for suitable lifestyle changes and self-management) (25, 27, 33-35). Six studies compared NW training to other types of exercise programs other than CCVR, such as TW (24, 28, 29) and treadmill training (31, 36, 37). Finally, in the 2 studies focusing on post-stroke survivors, NW training was performed on a treadmill (Nordic treadmill training, NTT) (36, 37).

Different durations and frequencies of the NW programs were tested in the trials, ranging from 3 to 5 times a week for a total of 3 to 24 weeks. On average, interventions were carried out with a frequency of 4 ± 1.1 times/week (95% CI 3.1-4.9) and for a total duration of 7.8 ± 6.2 weeks (95% CI 3.3-15.7).

The effects of NW training on cardiovascular and functional outcomes were analyzed by all included studies, while QOL and non-motor symptoms outcomes were assessed by 8 trials (25-27, 29, 32, 33, 35, 37).

Regarding the three studies by Piotrowicz *et al.* that were found to originate from the same dataset (33-35), all the outcomes arising from their primary study (33) and any new additional outcomes reported in the secondary studies (34, 35) were considered. In case of shared outcomes, those reported in the study with a greater number of individuals were considered (Table 3).

A detailed description of the characteristics (sample, intervention groups, exercise protocols and main outcomes), and the main findings in terms of significance and clinical relevance of each trial are detailed in Tables 1-4.

***Table 1: Studies on the effects of NW in individuals with Coronary Artery Disease***

***Table 2: Studies on the effects of NW in individuals with Peripheral Arterial Disease***

***Table 3: Studies on the effects of NW in individuals with Heart Failure***

***Table 4: Studies on the effects of NW in post-stroke survivors***

*Quantitative data synthesis*

A meta-analysis was performed for 8 out of 15 studies (422 patients): 2 for CAD (23, 24), 2 for PAD (25, 27), 2 for HF (32-33), and 2 for stroke (36, 37) due to the limited availability of RCTs and the high heterogeneity among the interventions. These included NW combined with other interventions (26), differences in comparative exercise programs (28, 29, 31), studies investigating the same population (33-35), as well as manifold evaluation protocols (30).

*Studies on the effects of Nordic walking in individuals with Coronary Artery Disease*

Table 1 reports the main results from the 2 studies comparing a combined NW+CCVR program to a CCVR program alone for people with CAD (23, 24). 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 (Absolute ES, NW+CCVR>CCVR: from 0.1 to 1.9) (23, 24) (Table 1). Figure 2 reports the results of the quantitative analysis conducted on a pooled sample of 90 individuals. The studies were homogeneous (I2< 50%). Statistically significant differences were observed between groups in achieved METs (SMD: 0.49, 95% CI 0.04, 0.93; *p*= 0.03) and in the Up and Go Test (UGT) (SMD: 0.55, 95% CI 0.11, 1.00; *p*= 0.01) in favour of NW+CCVR.

No significant differences were detected between NW+CCVR and CCVR in functional mobility (Six-Minute Walking Test, 6MWT), strength assessments (Arm Curl Test, ACT and Chair Sit to Stand Test, CSST) and flexibility of the upper and lower parts of the body (Back Scratch Test, BST and Chair Sit and Reach Test, CSRT).

***Figure 2. Synthesis of results: NW+CCVR versus CCVR alone in Coronary Artery Disease***

*Studies on the effects of Nordic walking in individuals with Peripheral Arterial Disease*

Table 2 reports the main results of the studies on the effects of NW in individuals with PAD.

Overall, the authors agree on the effectiveness of NW in improving cardiovascular, functional and QOL outcomes (25-27, 30, 31). Two studies comparing NW training to TW reported larger improvements following the latter in terms of exercise duration (ExD) and oxygen uptake (peak VO2) (Absolute ES, TW>NW: from 0.1 to 0.6) (28, 29). While, for the 2 studies involving PAD that were sufficiently homogeneous (I2= 0%) to undergo meta-analysis (Figure 3, pooled sample: n= 101), pooled data demonstrated significant differences in ExD (SMD: 0.93, 95% CI 0.52, 1.34; *p*< 0.0001) and peak VO2 (SMD: 0.64, 95% CI 0.23, 1.04; *p*= 0.002) in favour of NW compared to control (25, 27). Figure 3 displays the forest plots of the main effects for the ExD and peak VO2 outcomes.

***Figure 3. Synthesis of results: NW versus Control groups in Peripheral Arterial Disease***

*Studies on the effects of Nordic walking in individuals with Heart Failure*

Table 3 reports the main findings arising from the comparison of NW training to CCVR (32) and UC programs (33-35) in individuals with HF.

CV, functional outcomes as well as QOL all showed improvement (32-35), with changes significantly greater following NW than CCVR or a UC program. Table 3 details the clinical relevance of the intervention-related changes by group as Hedges *g* (Absolute ES, NW>CCVR: from 0.03 to 0.3 and NW>UC: from 0.2 to 1.1) (32, 35).

In the meta-analysis of HF trials, the included studies (Figure 4) reported high homogeneity (I2 = 0 and 26%, respectively), although no significant differences were detected between groups in peak VO2 (pooled sample: n= 161; SMD: 0.29, 95% CI -0.10, 0.68; *p*= 0.14), and in 6MWT distance (pooled sample: n= 161; SMD: 0.29, 95% CI -0.04, 0.62; *p*= 0.08).

***Figure 4. Synthesis of results: NW versus CCVR or UC in Heart Failure***

*Studies on the effects of Nordic walking in post-stroke survivors*

Table 4 outlines the two studies on the effects of NW performed on a treadmill (NTT) and a traditional treadmill training without arm swing (TT), in post-stroke survivors (36, 37). Larger improvements were observed after NTT than TT with moderate to high ES (Absolute ES, NTT>TT: from 0.5 to 3.3). Following meta-analysis (Figure 5, pooled sample: n= 50, Heterogeneity test: I2= 34%), a statistically significant difference in 6MWT distance was observed in favour of NTT compared to TT (SMD: 0.80, 95% CI 0.08,1.52; *p*= 0.03).

***Figure 5. Synthesis of results: NTT versus TT in post-stroke survivors***

*Publication bias*

Visual inspection of the funnel plots (data not shown) revealed no asymmetry in each of the 12 outcome measures considered in the present meta-analysis, with studies gathered symmetrically around the center of the funnel. The absence of substantial publication bias was further confirmed by the non-significant Egger regression coefficients (all one-tailed *p* values > 0.05).

**Discussion**

This systematic review and meta-analysis highlights the benefits of NW training pertaining to 4 major subgroups of CVD (CAD, PAD, HF and stroke). Out of 15 RCTs that were systematically reviewed (n= 766), meta-analysis was performed for 8 studies (n= 422). Regardless of CVD subgroups, NW proved superior to non-active control groups and, when combined to CCVR, it seems to lead to larger improvements than CCVR alone on exercise capacity and fitness. Findings proved less consistent when NW was compared to other exercise-based interventions.

In individuals with CAD, NW-based CVR revealed larger effect estimates in METs and dynamic balance (UGT) (23, 24). Improvements in exercise capacity have been previously associated to improved survival in IwCVD (38-41). As an example of such relationship, the increase of 1 MET in exercise capacity is associated with a 12% of improved survival (42). However, it should be pointed out that in the CAD studies included in the present review (23, 24), NW was administered in combination to CCVR programs, possibly resulting in an additive effect due to the increased workout volume. Further studies are warranted to determine the role played by the specific type of intervention rather than the volume of exercise.

In PAD population, the significant improvements in ExD and peak VO2 observed in favour of the NW groups compared to controls (25, 27) can be interpreted as particularly appealing since increases in these variables have been previously associated to a higher QOL and to enhanced life expectancy (43). However, such findings need to be verified by further adequately powered and supervised RCTs (44), especially directed to compare and clarify the advantages of NW training with those that arise following a TW program specifically addressed to individuals with PAD.

NW has been portrayed as a feasible form of exercise that can be adapted to different fitness levels, even in people with HF and low exercise tolerance (45). In these individuals, no significant difference were found between NW-based interventions and CCVR or UC programs for peak VO2 and functional mobility (32, 33). However, it should be taken into account that the individuals enrolled in these protocols showed a satisfying level of functional mobility already at baseline (6MWT) (Keast *et al.* NW: 430±137 m; CCVR: 503±106 m; Piotrowicz *et al.* NW: 428±93 m; UC: 439±76 m), as demonstrated by the comparison with normative data available for this population (average distance walked: ranged from 310 to 427 m) (46).

In post-stroke survivors, the observed improvements in 6MWT distance were compared to previously reported cut-offs for meaningful effects (Minimal Detectable Change, MDC; Minimal Clinically Important Difference, MCID) to establish the practical relevance of the intervention-induced changes (36, 37). Eng *et al.* (2004) estimated a MDC of +34.37 m to be exceeded in order to consider any improvement in 6MWT as meaningful in this population (47). This cut-off was surpassed in both included studies (+38.9 and +50.1 m, respectively) (36, 37). In addition, Perera *et al.* (2006) (48) estimated the MCID for 6MWT as an increase of at least 50 m following rehabilitative interventions. This threshold was exceeded only in the study by Kang *et al.* (37) following NTT (NTT: +50.1) but not TT (+20.32 m). On a speculative level, we offer that the positive findings detected following NW may be partly explained by the additional engagement of the upper part of the body. In view of this specific feature, NW has been proposed as potentially helpful in the rehabilitation programs of specific neurological diseases (49-51). Indeed, NW poles can provide further stability and better trunk posture over time, which is a particularly appealing for individuals presenting motor-functional impairments, postural instability and fear of falling, as is the case of post-stroke survivors.

*Critical appraisal of the findings and Study limitations*

Despite a comprehensive search strategy, our study highlights the paucity of data on NW in IwCVD, with only 8 studies eligible for meta-analysis. Adequately powered RCTs with common outcomes across sub-categories of IwCVD remain necessary to validate our findings.

Due to the overall low to moderate quality of the studies included in the present review (median PEDro score: 5), cautious interpretation of the studies’ findings is recommended, particularly for studies with a higher risk of bias (PEDro score ≤ 4) (23, 30, 31, 34, 37). These studies lacked important methodological steps such as blinding of assessors and analysis based on intention-to-treat, which may have biased the present estimates.

High heterogeneity was detected among the studies, which prevented data pooling across larger samples. In particular, the protocols differed for the modalities of assessment even when similar variables were evaluated. For instance, although the secondary outcomes describing QOL and non-motor symptoms were assessed in the majority of the RCTs (8 studies), discrepancies in the evaluation protocols prevented proper aggregation of the data.

Gender bias needs to be taken into consideration since only 11% of the total population in the included studies were women, which raises concerns considering that CVD is still the major cause of death in women over the age of 65 years (52). The risk of heart disease in women is often underestimated due to the misconception that females are *'protected'* against CVD by their sex hormones (53). Over the past two decades, however, the prevalence of CAD has increased in middle-aged women (35 to 54 years), while declining in similarly aged men (53). Furthermore, traditional well-established risk factors such as sedentary behavior, cigarette smoking and dyslipidemia contribute to CVD at least as much in women as in men, if not more (54, 55). In view of the gender imbalance, results of this study should be applied with caution to women.

Finally, the NW protocols reviewed in this study vary widely in terms of intensity, frequency, duration, progression of exercise and outcomes measured, contributing to a lack of generalizability.

Taken as a whole, these results reinforce the practical benefits of NW for IwCVD, but future prospective studies using standardized and structured training protocols are necessary to objectively quantify the benefits of NW training, especially in other CVD areas (*i.e.*, patients with chronic kidney disease, congenital heart disease patients, heart transplant recipients), for which the CV effects of NW programs have not yet been investigated.

**Conclusion**

Our systematic review and meta-analysis on NW-based interventions in secondary prevention of CVD has shown that NW training improves exercise capacity in IwCVD, whether performed as a standalone form of physical activity or in combination with CCVR programs. However, existing studies are small, heterogeneous and of limited quality.

Given its feasibility, affordability and preliminary evidence supporting its health benefits, high quality, adequately powered RCTs evaluating NW are warranted to justify its inclusion as a complementary tool in CCVR programs for IwCVD.

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**Conflict of interest**

The Authors declares that there is no conflict of interest.

**Author contributions**
LC, AM, GM and JCK contributed to the conception and design of the work. LC, AM, TJY and PPB contributed to the acquisition, analysis and interpretation of data for the work. LC, AM and TJY drafted the manuscript. All the authors critically revised the manuscript and gave final approval. All agree to be accountable for all aspects of work ensuring integrity and accuracy.

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