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# Physiological Responses Associated with Nordic-Walking and Walking in Middle-age Women

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**ABSTRACT**

This study aimed to analyze the influence of supervised 12-week walking (W) and Nordic-walking (NW) programs on changes in specific physiological parameters in middle-aged women 55.40 ± 7.87 and 52.58 ± 6.91 years of age, respectively. Body mass, fat tissue percentage, muscle tissue percentage, systolic blood pressure, diastolic blood pressure, resting pulse, and maximum oxygen uptake were measured at the beginning and end of the exercise program. Intra- and inter-group differences in physiological parameters as a function of the preparation period were analyzed using bootstrap analysis. Clinically reliable changes for a specific subject in the W and NW programs were analyzed using the Reliable Change Index (RCI). The results of this study indicate that more distinct differences were observed in the NW group. However, both programs improved the parameters studied. Nevertheless, an analysis of the RCI indicates that the W provides results similar to, if not better than, NW for increasing neuromuscular, cardiovascular, and cardiorespiratory fitness. This study leads us to the conclusion that the W is not less efficient than the NW for middle-aged women.

## Introduction

Although advances in medical sciences have led to an increase in human life span [1], one of its drawbacks is the inevitable deterioration of physical fitness levels associated with aging [2–6] such as age-related loss of strength [7], and deterioration of postural balance. Therefore, maintaining an appropriate level of neuromuscular fitness should allow one to avoid illnesses and disabilities [8, 9].

These observations motivated scientists and physical educators to look for economically and sociologically acceptable means of increasing two essential components of physical fitness. That is, aerobic and neuromuscular fitness. For many years, walking (W) has been considered one of the most efficient means of maintaining aerobic and neuromuscular fitness [10]. However, during the last decade, a derivative of W called Nordic-walking (NW) has emerged as a trendy aerobic activity [11]. The difference between W and NW is that NW engages the upper and lower body by mimicking cross-country skiing, while W engages only the lower body. Some reports also indicated that NW increases energy consumption and has higher efficiency than W [12].

Among the most profound studies on the efficacy of NW are those performed by Church et al. [12], Schiffer et al. [11], Porcari et al. [13], Figard-Fabre et al. [14], and Kocur et al. [15] and Latosik et al. [16]. Nevertheless, the main demerit of the reports mentioned above is the limited number of subjects studied: 11 women and 11 men [12], 15 women [11], 16 men and 16 women [13], 12 women [14] and 10 women [16]. Only Kocur et al. (24) performed the study on a large sample (NW -40, W-20 and control 20 patients). However, the reported results refer to subjects after acute coronary syndrome and cannot confirm the influence of NW or W on healthy subjects.

To expand our knowledge of differences between neuromuscular, cardiovascular and cardiorespiratory fitness in middle-aged women between NW and W, changes in a set of specific parameters as a function of 12-week W and NW programs were analyzed. The present study was conducted under the null hypothesis that the administration of supervised W and NW training programs should not exert differences in body mass (BM), fat tissue percentage (FT), muscle tissue percentage (MSC), systolic blood pressure (SBP), diastolic blood pressure (DBP), resting pulse (rP) and maximal oxygen uptake ($VO_2$max).

## Materials and Methods

In the present study, we analyze the differences induced by W and NW in BM, FT, MSC, SBP, DBP, rP, and $VO_2$max before (*ante-spacium; as*) and after (*post-spacium; ps) the* W and NW programs. Statistical differences in the parameters studied were evaluated using 95 % confidence intervals (CI) derived by bootstrap analysis. Furthermore, clinically reliable changes for a specific subject in the W and NW programs were analyzed using the Reliable Change Index (RCI). To ensure that the observed differences were related only to the applied programs, subjects were selected by simple random sampling in the W or NW program.

Subjects were recruited through advertisements. Volunteers were asked to meet the inclusion criteria of at least 40 years of age and to be generally in good health as assessed by a general practitioner. All subjects were assigned by simple random sampling to the W or NW group. However, the final decision to join or quit the training group was left to the individual subjects.

Fifty women in each test group, with the following phenotypes presented as mean ± SD, participated in the study: age (years) W: 55.40 ± 7.87, NW: 52.58 ± 6.91; height (cm) W: 160.30 ± 5.21, NW: 163.54 ± 5.06; weight (kg) W: 81.00 ± 12.39, NW: 81.08 ± 12.08. The experiment consisted of a fully supervised 12-week W or NW program composed of three 90-minute exercise sessions per week [17]. All measurements were made one day before and after the experiment.

Subjects were informed about the purpose, procedures, benefits, and time of this study. Written informed consent was obtained from all subjects before testing, and the Regional Medical Ethics Committee approved the study protocols (KB-15/13).

All exercise sessions were conducted outdoors and consisted of a 15-minute warm-up followed by 60 minutes of W or NW exercises and a 15-minute cool-down period. Cooling periods included stretching exercises of the calf muscles, hamstrings, groin muscles, and obliques, followed by breathing exercises. Because the general objective of training exercises in middle-aged women is to improve cardiorespiratory, cardiovascular, and neuromuscular fitness, subjects were asked to adjust their walking pace to such an intensity that their heart rate should oscillate between 55 and 69 % of an age-dependent maximum heart rate [17].

Maximal heart rate was expressed using the following formula: Peak HR = 206–0.88 * (age) [18]. Heart rate was monitored with a Polar S-610 heart rate monitor (Polar Electro Oy, Finland).

Body weight and height were measured with a standard physician's scale and a stadiometer. FT % and MSC were evaluated using a Soehnle Body Balance Comfort FS5 apparatus (LEIFHEIT AG, Germany), applying leg-to-leg bioimpedance [19, 20].

Resting SBP and DBP, as well as rP, were analyzed in a laboratory environment using an Omron HEM-907XL apparatus (Omron Healthcare, Inc., IL, USA). Subjects rested quietly for approximately 10 to 15 minutes before measuring SBP, DBP, and rP. Each measurement consisted of the average of three consecutive readings.

The level of $VO_2$max was evaluated using the Rockport Walking Institute Test [21] using the following formula:

$VO_2$max ml · kg$^{-1}$ · min$^{-1}$ = 132.853–0.0769 (weight) – 0.3877 (age) + 6.315 (sex) – 3.2649 (time) – 0.1565 (resting pulse).

*Diet*: During the 12-week test period, all subjects were provided a list of foods they should not consume during the experiment period. The list contained the following diet rules: 1/no high glycemic index foods (GI > 75), 2/no high-fat foods, 3/no eating after 7 pm or 3 hours before sleep, 4/drink at least 1.5 L of water per day, 5/eat five times a day to cover a total of 1900 kcal/day (based on the provided nutritional value of foods table [22]), and 6/do not drink alcohol during the test period. All subjects were also asked not to change other lifestyle habits and especially not to diet to lose weight.

All measurements were performed on an empty stomach between 9 am, and 10 am. Subjects were advised to be well hydrated, limit physical activity the day before the evaluation, and remain physically inactive the night before and the morning of the test.

The CIs of the difference in means in the parameters studied were analyzed by bootstrap analysis. In the analysis, repeated random samples of the same size as the original sample were drawn with replacements of the original data. The number of bootstrap resamples for constructing CIs was 10,000 [23, 24]. CIs were calculated using the bias-corrected and accelerated (Bca) method [25].

The clinically significant change in the specific parameter for a specific subject in the W or NW group was evaluated by the RCI [26–28]. RCI values < -1.96 or > 1.96 were indicative of clinically significant changes. The following formula was used for the calculation of (Reliable Change Index) RCI:

where $x_1$ is the subject's specific test score before the administration of a training program, $x_2$ is the subject's specific test score after the administration of a training program, and $s_{diff}$ is the standard error of difference given by the following formula: . The $S_E$ or standard error of the measurement is calculated accordingly to the

▶ **Table 1** *Ante spacium* statistical differences between Walking (W) and Nordic-walking (NW) in means for body mass (BM), fat tissue percentage (FT %), muscle tissue percentage (MSC %), systolic blood pressure (SBP), diastolic blood pressure (DBP), resting pulse (rP), and maximal oxygen uptake ($VO_2$max). The * represent statistically significant differences between W and NW.

| Parameter | Mean W | Mean NW | |
|---|---|---|---|
| BM | 81.00 | 81.08 | |
| FT % | 43.27 | 42.22 | |
| MSC % | 28.50 | 28.32 | |
| SBP | 129.22 | 130.08 | |
| DBP | 92.62 | 96.16 | * |
| rP | 72.52 | 72.92 | |
| $VO_2$max | 21.07 | 31.83 | * |

▶ **Table 2** *Ante-spacium (as) vs. post-spacium (ps)* data represented as lower (lCI) and upper (uCI) 95 % confidence intervals of the differences in means and the mean values for body mass (BM), fat tissue percentage (FT), muscle tissue percentage (MSC) , systolic blood pressure (SBP), diastolic blood pressure (DBP), resting pulse (rP), and maximal oxygen uptake ($VO_2$max) in the Walking (W) group.

| Parameter | *as* | *ps* | *Statistical significance* |
|---|---|---|---|
| BM | 81 | 78.8 | * |
| FT | 43.3 | 41.1 | * |
| MSC | 28.5 | 27.6 | * |
| SBP | 129.2 | 125.8 | * |
| DBP | 91.6 | 89.8 | * |
| rP | 72.5 | 70.6 | * |
| $VO_2$max | 21.1 | 22.9 | * |

▶ **Table 3** *Ante spacium (as) vs. post spacium* (ps) data represented as lower (lCI) and upper (uCI) 95 % confidence intervals of the differences in means and the mean values for body mass (BM), fat tissue percentage (FT), muscle tissue percentage (MSC) , systolic blood pressure (SBP), diastolic blood pressure (DBP), resting pulse (rP), and maximal oxygen uptake ($VO_2$max) in the Nordic-walking (NW) group.

| Parameter | *as* | *ps* | *Statistical significance* |
|---|---|---|---|
| BM | 81.2 | 77.7 | * |
| FT | 42.4 | 38.4 | * |
| MSC | 28.3 | 27.3 | * |
| SBP | 130.2 | 123.4 | * |
| DBP | 95.7 | 91.1 | * |
| rP | 73 | 69.4 | * |
| $VO_2$max | 31.8 | 34.5 | * |

equation , where $s_1$ is the standard deviation of the pretreatment experiment group and $r_{12}$ is the test-retest reliability of the measure [29].

## Results

The results obtained in this study are gathered in ▶ **Tables 1–4**. In ▶ **Table 1**, an analysis of the 95 % CI *ante-spacium* and mean values within the group exposes statistically significant differences in DBP

▶ **Table 4** *Post spacium* differences between Walking (W) and Nordic-walking (NW) in mean values for body mass (BM), fat tissue percentage (FT %), muscle tissue percentage (MSC %) , systolic blood pressure (SBP), diastolic blood pressure (DBP), resting pulse (rP), and maximal oxygen uptake ($VO_2$max). The * represents statistically significant difference.

| Parameter | Mean W | Mean NW | |
|---|---|---|---|
| BM | 78.82 | 77.65 | |
| FT % | 41.05 | 38.27 | * |
| MSC % | 27.57 | 27.39 | |
| SBP | 125.8 | 122.54 | * |
| DBP | 89.76 | 90.98 | |
| rP | 70.58 | 69.28 | |
| $VO_2$max | 22.97 | 34.49 | * |

and $VO_2$max between W and NW. However, we did not observe statistically significant differences between W and NW in the other parameters.

▶ **Table 2** reveals that the application of the 12-week W program induced a statistically significant decrease in all the parameters studied, except for $VO_2$max, where an increase was observed.

▶ **Table 3** shows that NW induced a statistically significant decrease in the level of all parameters studied except $VO_2$max, where, as in ▶ **Table 2**, an increase was observed.

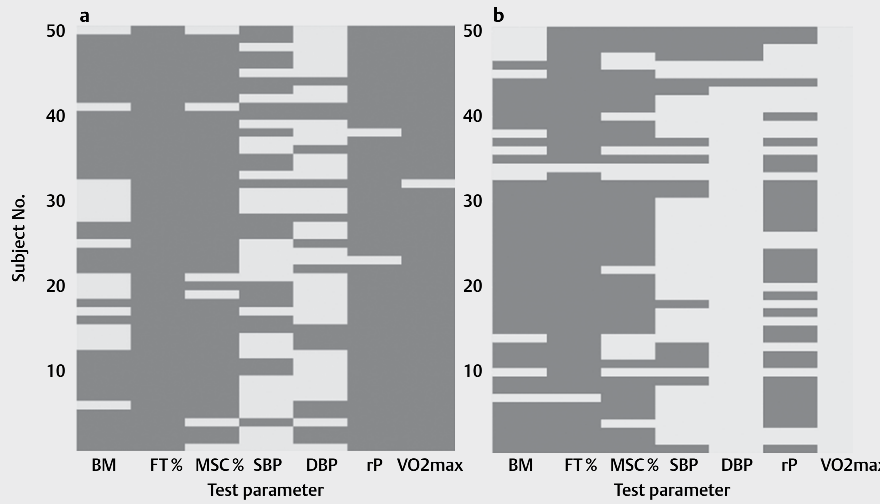
▶ **Table 4** reveals lower *post-spacium* values of BM, FT, MSC, SBP, and rP in the NW group than in the W group. However, the values of DBP and $VO_2$max were higher in the NW group than in the W group. CI analysis unfolds changes in BM, MSC %, DBP, and rP are statistically insignificant. However, statistically significant changes were observed for FT %, SBP, and $VO_2$max.

Analysis of the graphical representation of the RCI score of a study parameter as a function of a study subject revealed that W is the most capable means of increasing physical fitness than NW at the subject-to-subject level (▶ **Figs. 1a-b**). Examination of ▶ **Fig. 1a** exposes statistically significant changes in RCI in rP and $VO_2$max in most subjects in the W group. Analysis of ▶ **Fig. 1b** showed that, contrary to the W group, the NW group did not show statistically significant changes in VO2max. However, significant RCIs were observed in rP for ~80 % of the subjects in the NW group and ~50 % of the subjects in the W group. The RCI analysis of SBP and DBP revealed that participation in the W group resulted in more subjects undergoing clinically relevant changes than in the NW group. Clinically reliable changes in BM, FT, and MSC in both groups were observed in 70–90 % of subjects.

## Discussion

Because NW has recently become one of the most popular means to increase physical fitness levels among middle-aged and elderly women, we intend to verify the applicability of NW versus W to improve specific components of physical fitness training among middle-aged women.

In this report, we focus on analyzing changes in anthropometric, cardiovascular, and cardiorespiratory parameters as a function of 12-week supervised W and NW programs. Unlike other studies, we decided not to analyze changes in body mass index (BMI) as a function of training programs. The rationale behind such an




▶ **Fig. 1 a-b**. Unclustered heat map of clinically reliable change indexes after administering 12-week walking (**a**) and Nordic-walking (**b**) programs. White area indicates the lack of clinically relevant change -1.96 ≤ RCI ≤ 196, shaded the presence of clinically relevant change RCI < -1.96 or RCI > 1.96 in body mass (BM), fat tissue percentage (FT %), muscle tissue percentage (MSC %), systolic blood pressure (SBP), diastolic blood pressure (DBP), resting pulse (rP), and maximal oxygen uptake ($VO_2$max) for a specific subject.

approach lies in the findings of Lopez-Jimenez [30], who indicated that BMI in the normal range [31] does not necessarily improve longevity.

Compared to previous studies, our study design has the advantage of a significantly larger sample size. Therefore, we believe that the derived inferences are more representative than those presented by others [11–13]. The weak point of our study is the lack of a statistical 'equivalency' *ante-spacium* in all the parameters studied between two randomly assigned groups; statistically significant differences are present in DBP and $VO_2$max.

The previous study showed that NW increases exercise intensity due to the use of walking poles [32, 33], leading to increased oxygen consumption [12, 34]. Some reports also show that NW is an effective means of cardiac rehabilitation [35] and a way of inducing significant positive changes in BMI, total fat level, low- and high-density cholesterol levels, triglyceride levels, and waist circumference in women between 30 and 70 years of age [3]. Furthermore, comparative studies on physiological responses as a function of W, NW, and jogging reported a higher $VO_2$max for NW subjects than for those practicing W or jogging [11].

Analysis of VO2max levels revealed a smaller increase (1.8 ml • $kg^{-1}$ • $min^{-1}$) in the W group compared to the NW group (2.7 ml • $kg^{-1}$ • $min^{-1}$). Although the observed $VO_2$max in the W group was lower than the value reported by Kukkonen-Harjula et al. [36] (2.5 ml • $kg^{-1}$ • $min^{-1}$ for W and 2.6 ml • $kg^{-1}$ • $min^{-1}$for NW), statistical analysis rendered both studies equivalent. Furthermore, the percentage of increase in $VO_2$max in both groups was 8.5 % and was within the range reported in similar studies [36, 37].

The statistical validity of the observed changes was verified using RCI analysis depicted as heat maps (▶ **Figs 1a-b**). This analysis revealed that, contrary to W, changes in VO2max in NW, although statistically significant, are clinically insignificant. At present, we are unable to explain the observed phenomenon. However, it may be caused by two congruent phenomena, that is, the standard error was large enough to compensate for test-retest changes, and the $VO_2$max levels were close to their maximal capacity for analogous ages [38].

Therefore, the mean *ante-spacium* value of DBP in NW equal to 96.2 mmHg (stage 1 hypertension [39]) decreased to the normal level in *post-spacium* measurement. An analogous change in the W group was much less pronounced. A comparison of the reported changes with those on the effects of exercise and diet on blood pressure described previously [40] allows us to conclude that not the diet but the exercise program caused the observed changes. Thus, NW exerts a much stronger influence on DBP than W.

Among the interesting results of this study are changes in FT % and SBP. *Ante-spacium* levels of FT % and SBP were statistically equivalent between W and NW. However, *post-spacium* analysis exposed significant differences between W and NW. For FT % and SBP, the changes induced by the NW program were more pronounced than those induced by the W program. We did not observe statistically significant differences between *ante-spacium* and *post-spacium* between W and NW in BM, MSC %, and rP.

An amalgam of whole-group statistical analysis and subject-to-subject RCI analysis neither confirms nor disproves the statement that NW is more suitable for improving physical fitness levels among middle-aged women. Thus, a comparison of the data collected in ▶ **Tables 1–4** with the graphical representation of the changes in RCI in ▶ **Figs. 1a-b** shows that W is equally effective as NW, if not better, in improving the studied parameters.

Summarizing the results presented, we conclude that, although commercially successful, NW is not incontestably better than W in terms of clinical reliability for a single subject. Furthermore, we have some objections to the imminent advantage of using poles in the NW. Because a previous study has shown that the increase in oxygen uptake during NW is mainly due to the increase in activity of the shoulder and arm muscles [41], subjects can also increase their oxygen uptake during W by swinging their arms.

This report analyzes the differences in BM, FT %, MSC %, SBP, DBP, rP and $VO_2$max induced by supervised 12-week training programs using W or NW exercises. We show that both methods lead to an improvement in the parameters studied. At first glance, NW appears to be more effective than W. However, the analysis of clinically reliable changes, the RCI score, does not confirm this observation. In summary, W and NW can be interchangeably used to improve neuromuscular, cardiovascular, and cardiorespiratory fitness.

## Disclosure

The authors report there are no competing interests to declare.

## Data availability

Data are available upon request from the authors

### Conflict of Interest

The authors declare that they have no conflict of interest.

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