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Does Nordic Walking technique influence the ground reaction forces?

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ABSTRACT

Background: Nordic Walking (NW) practice has increased during the last decade, generating great benefits related to the reduction of ground reaction forces (GRF). However, there is still limited evidence regarding how the NW technique could affect GRF.

Research question: To analyze the effect of the speed and the differences in ground reaction forces (GRF) between NW with Diagonal technique (DT) versus Alpha technique (AT) and compare them with normal walking (W)

Methods: 29 male physically active sport science students were randomly assigned to one of the training groups: AT ($n = 15$) or DT ($n = 14$). After 5 technique familiarization sessions, participants performed 5 experimental trials on a walkway for both NW and W at two different walking speeds, previously randomized. A two-way repeated measures ANOVA analysis was carried out to find differences between speeds (preferred, fast) and gait (NW, W) as within-subject factors and NW techniques (DT vs AT) as between-subject factor.

Results: During NW, both technique groups (AT, DT) showed an increase in GRF variables compared to W, such as in stance time (2.9 % mean increment, $p < 0.01$, $ES = 0.3$; 95 %IC[−0.027, −0.008]), vertical force impact or vertical heel strike variables (4.9 % mean increment, $p < 0.01$, $ES = 0.4$; 95 %IC[0.101, 0.036]; 7.3 % mean increment, $p < 0.01$, $ES = 0.8$; 95 %IC[−0.133, −0.081] respectively). Moreover, AT group experienced significant lower forces at vertical force at midstance (10.1 % mean descent, $p = 0.036$, $ES = 0.3$; 95 %IC[−0.083, −0.009]) and higher forces at AP propulsive forces (23.7 % mean increment, $p < 0.001$, $ES = 0.6$; 95 %IC[0.078, 0.202) and ML max force (14.0 % mean increment, $p = 0.045$, $ES = 0.3$; 95 %IC[0.002, 0.026]) compared to DT group. Walking speed was significantly higher during NW (Preferred: 1.89 ± 0.18 m/s; Fast: 2.17 ± 0.21 m/s) compared to W (Preferred: 1.76 ± 0.15 m/s; Fast: 2.04 ± 0.19 m/s) in both speed conditions.

Significance: NW favours an increase in GRF and speed in comparison with Walking, independently of the technique, with no evidence that justifies the use of one technique or another.

1. Introduction

Nordic walking (NW) is a modality of exercise where the active use of a pair of specially designed poles has been added, constraining the participant to a specific pattern of walking with enhanced arm movement [1,2]. In this modality, the practitioners should place the poles on the ground at an acute angle, promoting a correct posture during exercise, what makes it suitable for adults and the elderly [1,2]; and it has been demonstrated to be suitable for diverse pathologies because that exerts beneficial effects on those populations [3]. Moreover, during locomotion, there is an opposite movement between arms and legs, with similar low impacts as walking [1]. Additionally, during the NW technique, the base of support is wide, which facilitates balance, and the footstep angle is maintained in a neutral position promoting an effective step.

The regular NW practice has been improved in the last decade, in part due to the scientific evidence regarding health benefits associated [1,3]. Some of that benefits are related to physiological improvements related to regular NW practice, as the increase in VO2max, the decrement of body fat, or the increment of high-density lipoprotein (HDL)

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after training [3]. Form a biomechanical point of view, the reduction of ground reaction forces (GRF) was one of the most promising benefits of NW reported by different studies [4,5]. However, it was observed that GRF during the initial phase of the strike was higher compared with walking [6], and increase the walking velocity at the self-selected [6], being higher its mechanical work and metabolically more demanding than walking. On the contrary, it was shown that the NW practice reduces the forces at the moment of take-off by approximately 8 % due to the active action of the arms on the poles [6]. Despite these controversial results and the lack of knowledge regarding the effect of the NW technique on the biomechanical response, there is still limited evidence regarding how could affect the NW technique to the GRF.

As well as in other sport modalities, there are different technical patterns for the same activity, with different benefits associated to each one. In this sense, in NW there are two main pole walking techniques: diagonal technique (DT) and alpha technique (AT) [7]. While the DT technique is identified with the beginning of NW in Finland, AT is a technique that emerged in the last decades with the International Nordic Fitness Organization (INFO). However, to the authors' knowledge, there is a lack of studies comparing both techniques since most of the studies have assessed the effects of NW compared with walking [4,6,8], as well as the long-term effect of both modalities practice [9–11].

The main difference between techniques is based on the position of the trunk during the action of the arms and the action of the legs [7].

Specifically, the Alpha technique (AT) proposes a model where the body must walk upright, without making long strides and keeping the arms straight during the execution, while the Diagonal technique (DT) proposes a technique that seeks a position of the trunk more inclined forward, performing longer strides and active use of the arms (without limitation of flexion or extension) during practice (Fig. 1).

The aim of the present study was, therefore, to analyze the differences between walking and NW considering both techniques (AT and DT) and the effect of the speed on GRF. It was hypothesized that both NW techniques would reduce GRF in comparison with W, explaining the discrepancy of the previous literature. Moreover, NW would increase the walking speed compared to W.

2. Material & methods

2.1. Participants

Twenty-nine physically active sport science students were randomly assigned to one of the training groups: Alpha Technique (AT, n = 15, age = 20 ± 1 years; body weight (BW) = 75.5 ± 10.2 kg; body height = 179.1 ± 8.8 cm) or Diagonal Technique (DT, n = 14, age = 19 ± 1 years; body weight (BW) = 72.1 ± 7.6 kg; body height = 177.6 ± 5.2 cm). None of the participants had previous experience in NW practice, and none of them deliberately trained for NW out of the learning sessions.

Inclusion criteria included no history of lower extremity injuries within the last 6 months, no previous use of foot orthoses, and being physically active (exercise practice 3 times a week for at least 30 min per session) [12]. All participants gave written informed consent before participation. The study procedures complied with the Declaration of Helsinki and were approved by the University ethics committee. A sample size calculation was performed based on the ANOVA repeated measures within-between factors design, using the G-Power 3 software (version 3.1.9.7, Düsseldorf, Germany). This analysis indicated that at least a sample of 26 volunteers was required to detect significant differences in the different variables analyzed with a minimum detectable effect size of f = 0.85 (large) (α = 0.05, power = 0.95).

2.2. Procedures

Prior to the testing session, participants made five familiarization sessions of one hour and a half each (7.5 h of total practice) in order to learn the corresponding technique according to the randomly assigned group. Familiarization sessions consisted of technical teaching sessions where participants were taught how to perform each NW technique according to International Nordic Walking Association (INWA) technical model for the DT group, and the INFO[7]-ANE for the AT group. All sessions were supervised by a sports science professional and experienced instructor of NW (>10 years). During NW test, participants of the DT group walked with the trunk bent slightly, and the AT group walked with the trunk more upright. On the other hand, participants walked with their normal walking pattern during the walking test (W).

At the experimental trials, participants did a standardized warm-up of 5 min at sub-maximal aerobic speed of NW followed by some stretching and technical exercises. Afterwards, participants walked along a 20 m long × 1.5 m wide walkway at two speed conditions: freely chosen speed (preferred speed or V1), and fast speed (fast speed or V2 = preferred plus 20 %) [6,13].

To calculate the preferred speed before the testing session, participants were asked to walk ten times on a preferred to vigorous intensity for both gait conditions (NW and W). Then, we discarded the fastest and the slowest repetition and we calculated the mean for each speed condition. Once the participants were familiar with the testing procedure, five trials for both NW and W at both speed conditions were performed in random order (Fig. 2). Participants rested for two minutes between repetitions.

A trial was considered valid when a complete foot strike was completely over the force platform and the walking speed fell within a 5 % deviation range of the trial speed.

2.3. Measures

Stance time, ground reaction forces (normalized to BW) and impulses were recorded with a force platform system sampling at a frequency rate of 500 Hz (Dinascan/IBV, IBV, Valencia, Spain) (Fig. 3). The force

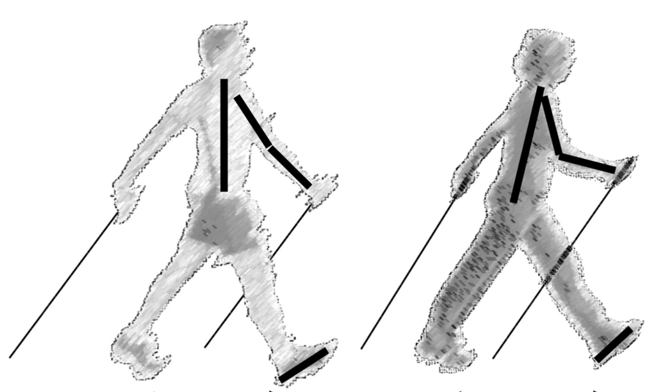

Fig. 1. Nordic walking techniques comparison. Left: Alpha technique (AT), Right: Diagonal technique (DT).

Fig. 2. Testing procedure.

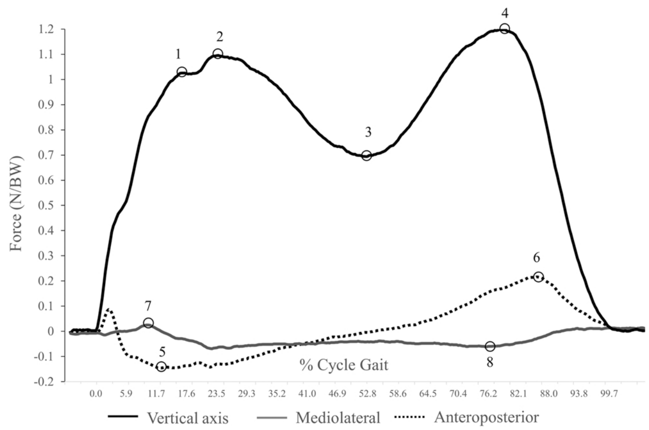

Fig. 3. Variables analysed during the gait cycle: (1) Vertical force impact heel strike; (2) Vertical force heel strike, (3) Vertical force midstance, (4) Vertical force takeoff, (5) Anteroposterior braking force, (6) Anteroposterior propulsive force, (7) Mediolateral maximum force, (8) Medriolateral minimum force.

platform was covered by a piece of the same material of the rest of the walkway surface to occult the force platform and to avoid changes at gait pattern of the participants. Additionally, a bullseye type image was placed at the end of the walkway at the same height as their eyes.

The speed was controlled by two photocells (Velleman PEM10D®, Gavere, Belgium) connected to an electronic timer (Chronopic, Chronojump BoscoSystem®, Barcelona, Spain), and located five meters apart from each other. Trials outside the ± 5 % allowance faster or slower than the target speed were discarded and had to be repeated. One step per trial was selected for analysis. This step needed to be over the force platform between the photocells to ensure that the measured speed corresponded to the mean speed at which the steps were performed.

2.4. Statistical analysis

The SPSS Statistics (SPSS v.26, Chicago, IL, USA) package was used for statistical analyses. After checking the normality of the variables (Shapiro-Wilk), a descriptive analysis of the data was performed. The sphericity assumption was verified by the Mauchly test. Then, a Two-Way Repeated Measures ANOVA was set up with speed (preferred, fast) and gait (NW, W) as within-subject factors, the 'Group of technique' (DT vs AT) as between-subject factor, and stance time, forces and impulse variables as dependent variables. When the variables did not follow a normal distribution, the U de Mann-Whitney test was applied.

To provide meaningful analysis for comparisons, the effect sizes (ES) were calculated (Cohen's d) [14]. Cohen's d was calculated by dividing the mean difference within groups by the root mean square of both standard deviations. The strength of the ES was determined as small (<0.50), moderate (0.50–0.79), or large (>0.80) [14], and confidence intervals (95 % CI) of the mean differences were also calculated. Significance was set at $\alpha = 0.05$. Results are presented as mean and

Table 1
Descriptive values (mean ± SD) and the main effect of walking speed (Preferred vs. Fast), gait (Normal walking vs. Nordic walking) and NW technique group (AT vs. DT) on speed, stance time, force and impulse variables at the three space axes for all the sample.

		Normal walking (kPa)				Nordic walking (kPa)			
		Preferred		Fast		Preferred		Fast	
Variable	Group	M	SD	M	SD	M	SD	M	SD
Speed (m/s)	Alpha	1.785[a]	0.165	2.085[a]	0.205	1.936[a]	0.175	2.217[a]	0.219
	Diagonal	1.734[a]	0.136	1.992[a]	0.176	1.841[a]	0.180	2.120[a]	0.199
Stance time (s)	Alpha	0.600[a, b]	0.051	0.540[a, b]	0.051	0.613[a, b]	0.042	0.560[a, b]	0.039
	Diagonal	0.599[a, b]	0.040	0.549[a, b]	0.042	0.617[a, b]	0.044	0.564[a, b]	0.041
Vertical component forces									
V impact heel strike (BW)	Alpha	1.268[a, b]	0.142	1.367[a, b]	0.168	1.334[a, b]	0.164	1.446[a, b]	0.190
	Diagonal	1.320[a, b]	0.194	1.418[a, b]	0.225	1.362[a, b]	0.145	1.489[a, b]	0.122
V heel strike (BW)	Alpha	1.285[a, b]	0.141	1.419[a, b]	0.160	1.387[a, b]	0.116	1.539[a, b]	0.146
	Diagonal	1.352[a, b]	0.099	1.442[a, b]	0.095	1.425[a, b]	0.088	1.553[a, b]	0.125
V midstance (BW)	Alpha	0.596[a, b]	0.093	0.472[a, b]	0.124	0.469[a, b c]	0.126	0.345[a, b, c]	0.126
	Diagonal	0.601[a, b]	0.119	0.481[a, b]	0.129	0.518[a, b, c]	0.109	0.387[a, b, c]	0.115
V take-off (BW)	Alpha	1.197[a]	0.068	1.228[a]	0.080	1.210[a]	0.061	1.243[a]	0.082
	Diagonal	1.223[a]	0.095	1.276[a]	0.124	1.208[a]	0.074	1.217[a]	0.105
AP component forces									
AP propulsive (BW)	Alpha	0.294[a, b]	0.056	0.481[a, b]	0.230	0.583[b, c]	0.268	0.600[b, c]	0.252
	Diagonal	0.305[a, b]	0.048	0.387[a, b]	0.116	0.429[b, c]	0.179	0.473[b, c]	0.184
AP braking (BW)	Alpha	-0.333[a, b]	0.095	-0.429[a, b]	0.161	-0.350[a, b]	0.080	-0.483[a, b]	0.204
	Diagonal	-0.310[a, b]	0.063	-0.472[a, b]	0.229	-0.372[a, b]	0.138	-0.418[a, b]	0.160
ML component forces									
ML maximum (BW)	Alpha	0.070[a, b]	0.031	0.083[a, b]	0.042	0.089[b, c]	0.044	0.106[b, c]	0.044
	Diagonal	0.080[a, b]	0.028	0.092[a, b]	0.037	0.083[b, c]	0.042	0.085[b, c]	0.042
ML minimum (BW)	Alpha	-0.074[a, b]	0.033	-0.083[a, b]	0.038	-0.090[a, b]	0.038	-0.103[a, b]	0.046
	Diagonal	-0.073[a, b]	0.024	-0.084[a, b]	0.037	-0.083[a, b]	0.030	-0.095[a, b]	0.040
Impulses									
V braking impulse (N s)	Alpha	200.6[b]	26.1	194.7[b]	26.0	206.5[b]	31.8	197.8[b]	30.5
	Diagonal	200.2[b]	25.6	194.2[b]	27.1	208.0[b]	26.1	200.0[b]	28.5
V propulsive impulse (N s)	Alpha	188.1[a, b]	49.5	164.1[a, b]	42.4	176.4[a, b]	43.7	152.4[a, b]	38.5
	Diagonal	176.4[a, b]	32.9	158.2[a, b]	30.2	175.1[a, b]	33.0	150.7[a, b]	28.6
AP propulsive impulse (N s)	Alpha	30.3[b]	4.5	31.4[b]	5.7	38.6[b, c]	8.0	38.6[b, c]	8.7
	Diagonal	30.0[b]	4.6	30.5[b]	5.8	35.7[b, c]	8.3	35.3[b, c]	10.3
AP braking impulse (N s)	Alpha	-30.9[b]	5.9	-31.5[b]	6.0	-33.3[b]	7.4	-34.3[b]	8.6
	Diagonal	-28.9[b]	5.7	-31.1[b]	6.6	-33.4[b]	8.0	-34.0[b]	7.6
ML propulsive impulse (N s)	Alpha	5.2[b]	4.4	5.9[b]	6.1	3.6[b]	3.3	4.0[b]	3.8
	Diagonal	7.1[b]	6.1	7.4[b]	6.4	7.0[b]	7.3	6.0[b]	7.5
ML braking impulse (N s)	Alpha	-8.6[b]	7.4	-8.5[b]	7.1	-12.3[b]	7.9	-11.4[b]	7.2
	Diagonal	-10.2[b]	9.3	-9.3[b]	9.2	-11.4[b]	8.9	-12.8[b]	9.3

M = mean; SD = standard deviation; BW = times body weight; V = vertical axis; AP = anteroposterior axis; ML = mediolateral axis; a significant difference between Preferred vs. Fast Speed. b significant difference between Normal Walking vs. Nordic Walking, c significant difference between Alpha vs. Diagonal Technique.

standard deviation (SD).

3. Results

Results are presented in Table 1. Normality ($p > 0.153$), homoskedasticity ($p > 0.102$) and sphericity ($p > 0.060$) were verified in several variable and were analyzed by parametric procedures.

3.1. Effect of gait condition (Walking vs Nordic Walking)

During NW, both technique groups (AT, DT) showed higher values compared to W in stance time (2.9 % mean increment, $p < 0.01$, ES = 0.3; 95 %IC[−0.027, −0.008 s]), vertical force impact and vertical heel strike variables (4.9 % mean increment, $p < 0.01$, ES = 0.4; 95 %IC [−0.101, −0.036 BW]; 7.3 % mean increment, $p < 0.01$, ES = 0.8; 95 % IC[−0.133, −0.081 BW], respectively), at anteroposterior (AP) propulsive and braking force peaks (27.3 % mean increment, $p < 0.01$, ES = 0.7; 95 %IC[−0.180, −0.104 BW]; 4.6 % mean increment, $p = 0.039$, ES = 0.1; 95 %IC[−0.011, 0.049 BW] respectively), max and min mediolateral (ML) forces (10.9 % mean increment, $p = 0.014$, ES = 0.3; 95 % IC[−0.017, −0.003 BW]; 15.2 % mean increment, $p < 0.01$, ES = 0.4; 95 %IC[0.007, 0.021 BW] respectively), braking impulse at vertical, AP and ML axes (2.8 % mean increment, $p = 0.014$, ES = 0.2; 95 %IC [−10.646, −0.705 N s]; 9.1 % mean increment, $p < 0.01$, ES = 0.4, 95 % IC[1.784, 4.381 N s]; 24.2 % mean increment, $p < 0.01$, ES = 0.4; 95 % IC[1.416, 4.376 N s] respectively), and AP propulsive impulse (17.1 % mean increment, $p < 0.01$, ES = 0.9; 95 %IC[−7.710, −4.908 N s]).

Moreover, during NW, both technique groups (AT, DT) showed lower force and impulse values compared to W in vertical force at midstance (24.6 % mean descent, $p < 0.01$, ES = 0.8; 95 %IC[0.082, 0.130 BW]), and vertical and ML propulsive impulse (5.3 % mean descent, $p = 0.04$, ES = 0.2; 95 %IC[1.421, 16.039 N s]; 20.5 % mean descent, $p < 0.01$, ES = 0.2; 95 %IC[−0.004, 2.145 N s] respectively).

3.1.1. Effect of Nordic Walking technique (Alpha vs Diagonal)

Small differences between groups were observed during NW (Fig. 4). Concretely, the AT group experienced significant lower forces at vertical axes during heel strike at preferred speed (4.9 % mean descent, $p = 0.01$, ES = 0.5; 95 %IC[−0.110, −0.024 BW]) compared to the DT group. And lower forces at vertical take-off during fast speed (3.7 % mean descent, $p = 0.011$, ES = 0.5; 95 %IC[−0.083, −0.011 BW]).

Finally, significant differences were also observed between the NW techniques (Table 1). The AT group experienced significant lower forces at vertical force at midstance (10.1 % mean descent, $p = 0.036$, ES = 0.3; 95 %IC[−0.083, −0.009 BW]) compared to the DT group. Also, the AT group experienced significant higher forces at AP propulsive forces and ML max force (23.7 % mean increment, $p < 0.001$, ES = 0.6; 95 %IC [0.078, 0.202 BW]; 14.0 % mean increment, $p = 0.045$, ES = 0.3; 95 % IC[0.002, 0.026 BW] respectively); and higher AP propulsive impulse

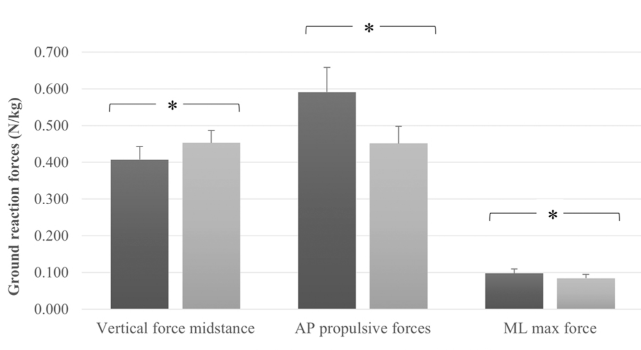

Fig. 4. Main differences between Nordic Walking techniques. AP: Anteroposterior; ML: Mediolateral; *: statistical differences ($p < 0.05$).

(8.1 % mean increment, $p = 0.036$, ES = 0.4; 95 %IC[0.621, 5.619 N s]). The small effect size observed in all variables, except for AP propulsive forces, make the differences negligible.

3.1.2. Effect of speed (preferred vs fast)

Walking speed was significantly higher during NW (Preferred: 1.89 ± 0.18 m/s; Fast: 2.17 ± 0.21 m/s) compared to W (Preferred: 1.76 ± 0.15 m/s; Fast: 2.04 ± 0.19 m/s) in both speed conditions (mean increase of 7.3 %, $p < 0.01$, ES = 0.3). In this sense, ANOVA test showed significant differences in force and impulse variables depending on the speed (Preferred vs. Fast) and type of walk (W vs. NW).

During W, increasing the speed (Preferred vs. Fast) led to a greater force values for vertical impact, vertical heel strike and vertical takeoff forces (7.1 % mean increment, $p < 0.001$, ES = 0.5; 95 %IC[−0.143, −0.056 BW]; 8.1 % mean increment, $p < 0.001$, ES = 0.9; 95 %IC [−0.148, −0.084 BW]; 3.2 % mean increment, $p < 0.01$, ES = 0.4; 95 % IC[−0.062, −0.018 BW] respectively); AP braking and propulsive forces (32.5 % mean increment, $p < 0.001$, ES = 1.0; 95 %IC[−0.178,−0.109 BW]; 27.8 % mean increment, $p < 0.001$, ES = 0.8; 95 %IC= 0.089, 0.160 BW] respectively); and ML min and max forces (14.3 % mean increment, $p = 0.02$, ES = 0.4; 95 %IC[−0.021,−0.004 BW]; 12.1 % mean increment, $p = 0.03$, ES = 0.3; 95 %IC[0.002, 0.018 BW] respectively).

Otherwise, there were lower stance time (10 % mean decrease, $p < 0.01$, ES = 1.2; 95 %IC[0.044, 0.067 s]), force values in vertical midstance force (25.8 % mean decrease, $p < 0.01$, ES = 1.1; 95 %IC [0.095, 0.150 BW]), and vertical propulsive impulse (13.4 % mean decrease, $p < 0.01$, ES = 0.5; 95 %IC[12.127, 31.414 N s]) when there exists a speed increase (Preferred vs. Fast).

During NW, similar results were observed, but without differences in AP propulsive forces and at ML max force when there exists speed increase (Preferred vs. Fast). Additionally, there was a lower level of vertical braking impulse at fast speed compared with preferred (4.0 % mean decrease, $p = 0.04$, ES = 0.3; 95 %IC[0.362, 16.342 N s]).

4. Discussion

This study analyzed the effect of both Nordic Walking techniques: Alpha Technique and Diagonal Technique, compared with Walking and the effect of the speed on GRF variables. There is an increasing evidence about the suitability of NW as a healthy physical exercise in special populations [1,3,9–11,15]. However, a large part of these studies have focused on the analysis of physiological variables, with great controversy surrounding their biomechanical benefits regarding GRF and joint loading [6,16,17]. Based on the results achieved, we reject the null hypothesis since the use of one of both NW techniques does not reduce GRF compared to walking, and there is no evidence to justify one technique instead of other. On the contrary, we accept the null hypothesis regarding the speed, since NW increases the preferred speed in comparison with walking exercise.

Regarding the differences between gait modalities (NW vs W), results showed significant differences ($p < 0.05$) on the variables analyzed. In this sense, stance time (2.9 %), vertical force impact (4.9 %) and vertical heel strike (7.3 %) were higher during NW compared to W. Park et al. [4], Encarnación-Martínez et al. [6], Grüneberg et al. [16] and Jöllenbeck et al. [17] also found this increase in GRF in NW during the initial phase of strike, which is caused by the increase in speed during NW due to a more active use of poles although GRF and poles have opposite directions; whereas at impulse, GRF decreases since poles and forces act in the same direction [6]. However, the results in the present study are opposites to the ones by Hagen et al. [18], since the propulsive forces were 17.1 % higher in NW in comparison with W.

On the contrary, a decrease in vertical force at midstance (24.6 %) and vertical propulsive impulse (5.3 %) can be observed in NW in comparison with W, which leads to an increase in AP propulsive (27.3 %) and braking force (4.6 %) probably due to the increase in stride length [4,19–21], and the increase in angle flexion of the ankle and hip during contact time experienced in NW [21]. At takeoff, both the forces of lower limbs and the forces applied to the poles are in the same direction, making the reduction in vertical takeoff forces logical [18].

Other studies [5,13], analyzed the differences between NW and W with more experienced participants, where an increase in GRF during skilled NW technique could be expected. However, the absence of kinematic data does not allow to assess the level of execution of the different techniques in order to analyze if kinematic differences could be related to differences in GRF. Despite this fact, the subjects in the present study were able to develop similar speeds to expert subjects such as those in the study by Hagen et al. [18] (between 5 and 8 km/h), with similar contact time (≈500–600 ms) and vertical forces at first contact (1.6–1.8 BW).

Regarding the differences between both techniques analyzed (DT & AT), the trunk position during DT (with more advanced center of gravity) may suppose greater step length. In addition, increases in vertical force at heel strike during preferred speed (4.9 %) and at takeoff during fast speed (3.7 %) can be observed. Moreover, results in this study show that AT provokes a reduction in vertical force at midstance (10.1 %), and an increase in AP propulsive force (23.7 %), ML max force (14.0 %) and AP propulsive impulse (8.1 %) compared to the DT group. During DT and due to the greater inclination of the body, the foot is responsible for decelerating the body by applying force on the ground at heel initial contact and the poles are responsible for accelerating the body forward by applying force using poles, so it should not be expected a load reduction at initial contact, since both forces have different directions [6,18,22].

Although small differences can be found between both NW techniques (DT & AT), the small effect size observed in all variables, except for AP propulsive forces, make the differences negligible and there is no evidence to justify the use of one technique instead of another. The differences between DT and AT observed in AP propulsive force could be related to the small changes in trunk inclination and, therefore, its influence on spatiotemporal variables. Likewise, it has been shown that the GRF are lower at the instant of take-off associated with the active use of the poles during the DT technique [6], although a less inclined trunk will make it difficult to apply forces on the ground and this could be reflected in an increase in GRF in the AP axis at the instant of take-off, a response similar to that obtained in the present study during the AT.

In this sense, despite the fact that GRF are greater in the NW in comparison with W, NW may continue being considered as a healthy alternative given that: a) allows to reach higher speeds, with similar metabolic cost to running achieved with no great increases in joint load [5]. The fast speed in this study was close to the speed of transition from walking to running [23], but without reaching the high GRF experienced on running, what might be appropriate for the prevention of diseases such as osteoporosis [6]; b) implies a higher metabolic cost (23–33 %) with a lower perception of effort [5,24]; c) according to running, NW allows to have a reduction in joint load of between 30 % and 40 % [5,18]; and d) despite the GRF increase showed in the present study, NW allows a reduction (37–50 %) in plantar pressure [13] and vertical GRF during the takeoff.

Taking into account the effects of gait type on speed, results of this study showed a higher speed (7.3 %) in NW compared to W, similar to results observed in previous studies [7,17,19]. This increase in walking speed during NW is related to the use of poles, at the same time that the forces in lower extremities are reduced at take-off and increased at strike even at faster walking speeds with poles [6], increasing the energy expenditure for similar rating of perceived effort [7,19].

In NW and W, an increase in speed (comparing fast vs preferred) led to an increase in GRF, becoming a determinant factor in GRF as other studies have also shown [3,6,18,20,21]. Specifically, higher speed led to an increase of vertical impact (7.1 %), vertical heel strike (8.1 %), vertical takeoff (3.2 %), AP braking force (32.5 %), AP propulsive force (27.8 %), ML min force (14.3 %) and ML max force (12.1 %). Nevertheless, at a higher speed there was a reduction in stance time (10 %), force values in vertical midstance force (25.8 %) and vertical propulsive impulse (13.4 %) during W, and additionally in vertical braking impulse during NW (4.0 %). The reduction in impulse variables could be associated with the use of poles during the takeoff phase, since poles do not act in the first phase of gait cycle, but it is when higher joint loads are experienced [6,21,22].

The main strength of the study lies in the use of an ecological methodology, since it describes the differences between NW and W favouring the spontaneity and nature of each gait modality. Likewise, the learning process followed with the participants replicates the teaching processes followed by the different social agents in the teaching of NW techniques. However, the present study is not without limitations. Since participants were instructed only in the NW condition and had no previous experience, results could be modified by the participant's experience. Therefore, future studies should investigate the effects in GRF of a skilled technique during a long period of familiarization or experience in NW.

Likewise, the free choice of speeds could influence the control of the variables analysed but maintains the ecological nature of the present study. Likewise, the participants used their own sports shoes, an aspect that could have altered the biomechanical response, but an ecological environment was chosen in order not to alter the natural gait of the participants.

5. Conclusions

Nordic Walking favours an increase in GRF and speed in comparison with Walking, independently of the technique. As far as GRF is concerned, no evidence justifies the use of one technique or another, since there is a similar biomechanical response.

Even though GRF are higher in NW than in W, these results could be of interest when prescribing physical exercise for the prevention of different diseases such as osteoporosis, since NW allows to reach higher speeds than W, with similar metabolic cost to running, but without reaching the high GRF experienced on running.

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CRediT authorship contribution statement

Alberto Encarnación-Martínez: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Ignacio Catalá-Vilaplana:** Funding acquisition, Investigation, Resources, Writing – original draft, Writing – review & editing. **Inmaculada Aparicio:** Investigation, Roles/Writing – original draft. **Roberto Sanchis-Sanchis:** Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. **Jose Ignacio Priego-Quesada:** Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. **Irene Jimenez-Perez:** Investigation, Roles/Writing - original draft**; Pedro Pérez-Soriano:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors report no conflicts of interest.

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