

Nordic Walking Enhances Oxygen Uptake without Increasing the Rate of Perceived Exertion in Patients with Chronic Obstructive Pulmonary Disease

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Key Words

Chronic obstructive pulmonary disease · Exercise physiology · Exercise test · Nordic walking · Physical exertion · Pulmonary rehabilitation

Abstract

Background: In healthy subjects, Nordic walking (NW) generates higher oxygen uptake ($\dot{V}O_2$) than standard walking at an equal rate of perceived exertion (RPE). The feasibility and positive outcomes of NW in patients with chronic obstructive pulmonary disease (COPD) have been reported. **Objectives:** The aim of the current study is to assess the physiological responses and RPE during NW in COPD patients. **Methods:** In 15 COPD patients [mean (SD) age 67 (9) years] with a forced expiratory volume in the 1st s of 55% (15)], $\dot{V}O_2$, minute ventilation and heart rate were measured with a portable system during the 6-min walking test (6MWT), incremental shuttle walking test (SWT), 6-min NW on solid ground (6mNW_{ground}) and 6-min NW on soft dry beach sand (6mNW_{sand}). The RPE using a modified Borg scale was assessed after each test. **Results:** 6mNW_{ground} and 6mNW_{sand} showed a higher $\dot{V}O_2$ plateau compared with the 6MWT and

peak $\dot{V}O_2$ measured during SWT [mean (SD) $\dot{V}O_2$ 21 (3), 22 (4), 18 (4) and 19 (5) ml·kg⁻¹·min⁻¹, respectively; $p < 0.05$ each]. However, no differences in RPE were observed among 6mNW_{ground}, 6MWT and SWT [modified Borg scale score for dyspnea 4.2 (2.0), 4.1 (1.8) and 4.3 (1.7), respectively; nonsignificant]. However, RPE in 6mNW_{sand} was significantly higher than in all the other exercise protocols [modified Borg scale score for dyspnea 5.2 (2.2); $p < 0.05$]. **Conclusions:** In COPD patients, the use of Nordic poles generates higher $\dot{V}O_2$ than standard walking with no differences in the dyspnea score. The results indicate the potential to enhance community-based training programs in these patients.

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Introduction

Nordic walking (NW) is a walking modality carried out using special poles with rubber or spike tips resembling Nordic style skiing and constitutes a common outdoor physical activity carried out by healthy people worldwide [1]. Moreover, NW has shown effectiveness as a training method to improve aerobic capacity and qual-

ity of life both in healthy subjects and patients with chronic conditions [2], including chronic obstructive pulmonary disease (COPD) [3].

The main purpose of NW is to exercise the upper limb and trunk muscles, which are not activated during standard walking. In healthy subjects, this increase in the exercising muscle mass translates into higher oxygen uptake [4] with equal [5, 6] or only slightly higher [7] levels of perceived exertion than during standard walking. However, there is no information on the physiological responses during NW in COPD patients in whom ventilatory limitation to exercise might lead to dynamic hyperinflation and a higher rate of perceived exertion (RPE) [8] that could eventually preclude generalization of the findings reported in healthy subjects [4–7].

The rationale behind the current study is that a better knowledge of the physiological responses during NW in COPD patients may facilitate the design of exercise training programs based on this modality of exercise. In the current research, we assessed the physiological responses during 6 min of NW on two different surfaces that were chosen because they are easily available in many urban environments: solid ground (6mNW_{ground}) and soft dry beach sand (6mNW_{sand}). The measurements were compared with those obtained during both the standard 6-min walking test (6MWT) and the incremental shuttle walking test (SWT).

Methods

Study Design

Sixteen clinically stable COPD patients (outpatients from the Hospital Clínic de Barcelona) were recruited from February to March 2010 for this study. Inclusion criteria were: (i) a diagnosis of COPD according to the criteria defined by the Global Initiative for Chronic Obstructive Lung Diseases [9]; (ii) no clinical evidence of major cardiovascular or neuromuscular diseases; (iii) no need for supplementary oxygen during exercise, and (iv) tolerance of the facemask during exercise testing. Of note, 10 of the 15 patients were on combined therapy with a long-acting anticholinergic compound and a long-acting β_2 -agonist, and the remaining 5 patients on inhaled corticosteroids combined with a long-acting β_2 -agonist. Moreover, 4 patients were also treated with simvastatin and 5 patients received furosemide for the treatment of hypercholesterolemia and arterial hypertension, respectively. All patients agreed to participate and signed the informed consent approved by the Ethics Committee for Clinical Research at Hospital Clínic de Barcelona.

For all patients, clinical history was obtained and physical examination was performed. Standard measurements included: (i) forced spirometry and static lung volumes (Master-Screen; Jaeger, Würzburg, Germany); (ii) lung single-breath CO transfer capacity (Master-Screen); (iii) arterial blood gases (partial O₂ and CO₂ pres-

sure in arterial blood) at rest (800 series; Ciba Corning, Medfield, Mass., USA), and (iv) bioelectrical impedance to determine body composition (Quantum X – Bioelectrical Body Composition Analyzer; RJL Systems, Clinton Township, Mich., USA).

Exercise Measurements

All patients became familiar with the NW technique after being coached by a specialized professional. All of them performed four exercise protocols in two different days in random order: (i) incremental SWT [10] to assess peak oxygen uptake ($\dot{V}O_2$); (ii) 6MWT [11]; (iii) 6mNW_{ground}, and (iv) 6mNW_{sand}. The two NW tests were performed according to the American Thoracic Society guidelines for 6MWT [11] to ensure comparability among exercise protocols.

During all exercise testing, patients breathed through an adult facemask (Hans Rudolph Inc., Kansas City, Mo., USA; 8940 series, made for Cortex Biophysik GmbH, Leipzig, Germany), which was carefully adjusted to the patient's face and checked for air leaks. The patients were able to move freely without discomfort because of the light weight of the equipment (650 g). The length of the poles (Spin Pole Package; Leki, Buffalo, N.Y., USA) was adjusted for each patient.

During testing, we performed breath-by-breath measurements using a portable system (MetaMax[®] 3B portable CPX system; Cortex Biophysik), which was calibrated before each test. Moreover, an online telemetric assessment of the quality of data collection was done during the testing. The measured variables during exercise testing were: $\dot{V}O_2$, carbon dioxide production, minute ventilation ($\dot{V}E$) and heart rate (HR). For both dyspnea and leg discomfort, RPE was assessed immediately after each protocol using a modified Borg scale ranging from 0 to 10 [12].

Statistical Analysis

Results are presented as means (SD), interquartile ranges or n (%) for continuous and categorical variables, respectively. We analyzed the time evolution of the Gaussian continuous variables and compared the four exercise protocols by means of a longitudinal mixed model for repeated measurements taking the intrasubject correlation into account. The characteristics of the slope for the variables $\dot{V}O_2$, $\dot{V}E$ and HR against time for the four exercise protocols were analyzed using a standard regression model. From that model, we assessed whether the slope was within a $\pm 5\%$ tolerability margin from 0 (i.e. flat slope), in order to evaluate the steady-state profile of each variable. A value of $p < 0.05$ was considered statistically significant.

Results

One of the 16 COPD patients was excluded because of the patient's inability to tolerate the face mask during the exercise protocols. The characteristics of the 15 patients finally assessed are displayed in table 1.

Figure 1 depicts the physiological responses throughout each of the four exercise protocols assessed in the study. Of note, the two NW tests and 6MWT showed a $\dot{V}O_2$ plateau from minute 3 of the testing. However, $\dot{V}E$ and HR showed a slow incremental profile throughout the 6-min exercise.

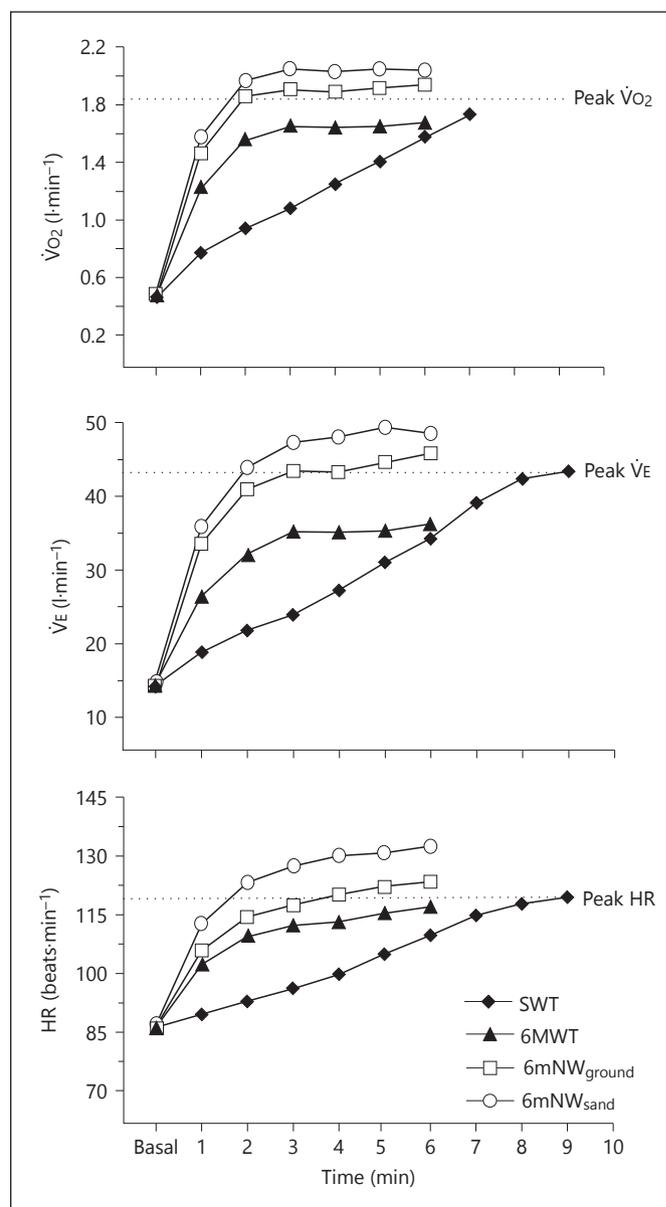
Table 1. Characteristics of the study group (n = 15)

Male sex, n	14 (93%)	
Current smokers, n	2 (13%)	
Age, years	67±9	(61–74)
Body mass index, kg/m ²	29±4	(25–31)
FFMI	23±3	(19–25)
mMRC	1.2±0.9	(0.5–2)
BODE	1.8±1.5	(1.0–2.5)
FEV ₁ , % of predicted	55±15	(42–64)
FVC, % of predicted	77±19	(61–85)
FEV ₁ /FVC	53±12	(42–61)
TLC, % of predicted	98±17	(84–104)
IC, % of predicted	78±19	(66–92)
RV, % of predicted	142±27	(128–161)
D _L CO, % of predicted	65±14	(54–77)
D _L CO/VA, % predicted	66±12	(53–75)
PaO ₂ , mm Hg	76±10	(67–84)
PaCO ₂ , mm Hg	40±5	(36–44)

Data are presented as means ± SD (interquartile ranges) or n (%) for numerical and categorical variables, respectively. FFMI = Fat-free mass index (kg/m²); mMRC = modified Medical Research Council dyspnea scale; BODE = BODE index; FEV₁ = forced expiratory volume in the 1st s; FVC = forced vital capacity; TLC = total lung capacity; IC = inspiratory capacity; RV = residual volume; D_LCO = diffusion capacity of the lung for carbon monoxide; D_LCO/VA = D_LCO to alveolar volume ratio; PaO₂ = partial O₂ pressure in arterial blood; PaCO₂ = partial CO₂ pressure in arterial blood.

Table 2 displays the physiological measurements expressed as mean values of the last 15 s of each test. Both 6mNW_{ground} and 6mNW_{sand} presented similarly higher $\dot{V}O_2$ (ml·kg⁻¹·min⁻¹) than the other two exercise protocols. Briefly, 6mNW_{ground} $\dot{V}O_2$ was 17 and 11% higher than the values obtained in 6MWT and SWT, respectively ($p < 0.05$ each), whereas 6mNW_{sand} $\dot{V}O_2$ was 22 and 16% above the measurements obtained during 6MWT and SWT, respectively ($p < 0.05$ each). As expected, peak $\dot{V}O_2$ (ml·kg⁻¹·min⁻¹) in the SWT was 6% higher than that observed in the 6MWT ($p < 0.05$). Similar trends were seen for both $\dot{V}E$ and HR (table 2). Of note, however, no differences in $\dot{V}E$ were seen between SWT and 6MWT. Moreover, 6mNW_{sand} HR was significantly higher compared with the other three exercise protocols (7, 11 and 13% for 6mNW_{ground}, SWT and 6MWT, respectively; $p < 0.05$ each) without differences in HR among these three exercise protocols.

No differences in dyspnea rating assessed after 6mNW_{ground}, 6MWT and SWT were observed (table 2). In contrast, 6mNW_{sand} showed significantly higher dyspnea rating compared with the other three exercise pro-

**Fig. 1.** $\dot{V}O_2$, $\dot{V}E$ and HR responses during the four walking protocols.

ocols: 21, 24 and 27% for 6MWT, 6mNW_{ground} and SWT, respectively ($p < 0.05$ each). Likewise, leg fatigue rating reported after 6mNW_{sand} was also significantly higher than that reported after 6mNW_{ground} (31%; $p < 0.05$).

Discussion

Main Findings

To our knowledge, this is the first study exploring the physiological responses to NW in COPD patients. The

Table 2. Physiological responses to the different exercise tests

	SWT		6MWT		6mNW _{ground}		6mNW _{sand}	
Total distance, m	420	(98)	537	(65) ^a	527	(58) ^{a, b}	375	(86) ^{a-c}
$\dot{V}O_2$, l·min ⁻¹	1.82	(0.46)	1.68	(0.45)	1.94	(0.53) ^b	2.04	(0.53) ^{a, b}
$\dot{V}O_2$, ml·kg ⁻¹ ·min ⁻¹	19	(5)	18	(4) ^a	21	(3) ^{a, b}	22	(4) ^{a, b}
$\dot{V}CO_2$, l·min ⁻¹	1.46	(0.35)	1.32	(0.35) ^a	1.59	(0.42) ^b	1.70	(0.46) ^{a, b}
$\dot{V}E$, l·min ⁻¹	42	(10)	36	(8)	46	(11) ^b	49	(13) ^{a, b}
HR, beats·min ⁻¹	119	(18)	117	(18)	123	(15) ^b	132	(15) ^{a-c}
Dyspnea, modified Borg scale	4.3	(1.7)	4.1	(1.8)	4.2	(2.0)	5.2	(2.2) ^{a-c}
Leg discomfort, modified Borg scale	3.3	(1.6)	3.2	(1.7)	2.5	(2.0)	3.6	(2.0) ^c

Data are means (SD) of the last 15 s in NW tests, and 6MWT and the last 5 s in the SWT. Dyspnea and leg discomfort ratios were assessed immediately after each test. ^a $p < 0.05$ vs. SWT, ^b $p < 0.05$ vs. 6MWT, ^c $p < 0.05$ vs. 6mNW_{ground}.

main findings were that: (1) NW (6mNW_{ground}) results in an increase in $\dot{V}O_2$, $\dot{V}E$ and HR levels compared with standard walking (6MWT); (2) $\dot{V}O_2$ levels achieved during the two NW modalities showed a steady-state profile indicating high but sustainable exercise intensity, and (3) the increase in oxygen uptake generated during 6mNW_{ground} does not translate into a higher RPE compared with standard walking (6MWT) in these patients.

Contributions Beyond the Existing Knowledge

Previous studies in healthy subjects [4–7] have reported a systematic increment in $\dot{V}O_2$ levels during NW compared with standard walking, ranging from 7 to 23%. The present investigation showed an increase of 17% in $\dot{V}O_2$ during 6mNW_{ground} compared with 6MWT and a parallel increase in $\dot{V}E$ (28%). Moreover, the current study clearly indicates that in patients with moderate-to-severe COPD, as previously reported in healthy subjects [5, 6], the increase in $\dot{V}O_2$ during 6mNW_{ground} was not accompanied by a parallel increase in RPE. Even more importantly, the $\dot{V}O_2$ profile during the two NW protocols (6minNW_{ground} and 6minNW_{sand}) indicated sustainability over time of this exercise modality irrespective of the walking surface. The changes in $\dot{V}O_2$ during NW can be reasonably attributed to the increase in exercising muscle mass. $\dot{V}O_2$ during NW exceeded $\dot{V}O_2$ peak assessed with SWT (table 2). It is well recognized that NW involves recruitment of the upper limb, trunk and lower extremity muscles, whereas standard walking is mostly reduced to lower limb muscle mass.

6mNW_{sand} presented significantly higher both dyspnea and leg discomfort scores than 6mNW_{ground}, but $\dot{V}E$ was similar between the two modalities of NW. We hypothesize that the characteristics of the pattern can be ex-

plained by different walking ergonomics due to the surface, i.e. higher surface friction and increased difficulty to keep in balance while walking over soft sand should be expected. The lower 6mNW_{sand} walking distance (–33%; $p < 0.05$) compared with 6mNW_{ground} (table 2) supports this interpretation.

Clinical Applicability of the Results

One of the central challenges of pulmonary rehabilitation programs for COPD patients [13] is to provide long-term cost-effective strategies aiming to enhance daily physical activity of these patients [14]. Therefore, NW has been reported to be an effective method to improve both aerobic capacity and physical activity in patients with COPD [3]. The current study reinforces the message by providing novel information on the physiological responses to NW in COPD patients.

We would like to stress the potential of NW as an exercise training method for COPD patients in urban environments, highlighting that NW generates higher intensities than standard walking, but the cardiorespiratory challenge is still sustainable and can be applied to train skeletal muscles. Consequently, we may obtain a higher training stimulus with similar perceived effort. Moreover, for the practice of NW, urban environments provide both an easily accessible and attractive setting as a low-tech, low-cost training approach that may result in enhanced long-term adherence to the program.

Strengths and Limitations

The current results may show limitations for generalization of the main message to very severe COPD patients that were not included in the study because of their inability to support the face mask and, in some

cases, the need of long-term oxygen therapy. However, while acknowledging this fact, we would like to stress that patients with moderate/severe disease are the target for this kind of community-based preventive interventions with the aim to improve their health status and, ultimately, to delay disease progression. Finally, the reliability of the results is based on the study design and the quality control procedures, including equipment calibration and telemetric data collection and control during the tests.

Conclusions

The results of the study suggest that NW could be an appropriate walking modality to train patients with moderate to severe COPD because it generates higher exercise intensity at the same RPE compared with standard walking. However, further studies comparing the impact of

NW and standard walking on health outcomes in COPD patients with different degrees of COPD severity are needed before NW is included into community-based rehabilitation programs.

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