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Original Article

Effects of Nordic walking and walking on spatiotemporal gait parameters and ground reaction force

Seung Kyu Park, PhD, PT[1)], Dae Jung Yang, PhD, PT[1)], Yang Hun Kang, PT[1)], Je Ho Kim, PhD, PT[1)], Yo Han Uhm, PT[1)], Yong Seon Lee, PT[2)*]

[1)] *Department of Physical Therapy, Graduate School of Physical Therapy, Sehan University, Republic of Korea*
[2)] *Department of Physical Therapy, Mokpo Won-Kwang Oriental Hospital: 577-1 Sang-dong, Mokpo, Junnam, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to investigate the effects of Nordic walking and walking on spatiotemporal gait parameters and ground reaction force. [Subjects] The subjects of this study were 30 young adult males, who were divided into a Nordic walking group of 15 subjects and a walking group of 15 subjects. [Methods] To analyze the spatiotemporal parameters and ground reaction force during walking in the two groups, the six-camera Vicon MX motion analysis system was used. The subjects were asked to walk 12 meters using the more comfortable walking method for them between Nordic walking and walking. After they walked 12 meters more than 10 times, their most natural walking patterns were chosen three times and analyzed. To determine the pole for Nordic walking, each subject's height was multiplied by 0.68. We then measured the spatiotemporal gait parameters and ground reaction force. [Results] Compared with the walking group, the Nordic walking group showed an increase in cadence, stride length, and step length, and a decrease in stride time, step time, and vertical ground reaction force. [Conclusion] The results of this study indicate that Nordic walking increases the stride and can be considered as helping patients with diseases affecting their gait. This demonstrates that Nordic walking is more effective in improving functional capabilities by promoting effective energy use and reducing the lower limb load, because the weight of the upper and lower limbs is dispersed during Nordic walking.
Key words: Nordic walking, Ground reaction force, Spatiotemporal gait parameters

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INTRODUCTION

Walking is one of the most popular types of outdoor recreation. Humans can lead efficient daily lives by adjusting their walking patterns in various ways during exercise. However, walking for long hours consumes much energy and may cause fatigue[1)]. Also, general walking does not efficiently control calories, the heart rate, the oxygen consumption, and the respiratory exchange ratio during the activity[2)]. However, Nordic walking activates the upper limb muscles and lowers the efficiency of recruitment and weight-bearing of the lower limbs, as the duration of the fatigue lengthens[3–5)]. The primary purpose of using a pole is to be able to use the upper limb muscles, which are not normally used in walking, and to facilitate high-intensity exercise with the minimum effort by adjusting the energy consumption of the body[6)]. According to the research of Schwameder, Nordic walking increased the strengths of the upper and lower limb muscles, and the poles dispersed the body weight; furthermore, it was found to lower the vertical ground reaction force of the knee and significantly change the knee extension angle[7)]. Therefore, the present study analyzed the effects of Nordic walking and walking on spatiotemporal parameters and ground reaction force, so that it would be possible to suggest an efficient means of walking for people who walk for health.

SUBJECTS AND METHODS

This study was performed with 30 young males who volunteered to participate. The subjects were divided into a Nordic walking group of 15 subjects and a walking group of 15 subjects. All subjects signed an informed consent form approved by the Sehan University Institutional Review Board. The general characteristics of the subjects were measured using an InBody J05 system (Biospace, USA). The Nordic walking group's average age was 23.2 ± 4.6 years, average height was 167.2 ± 4.3 cm, and average weight was 63.4 ± 4.7 kg. The walking group's average age was 23.8 ± 3.9 years, average height was 169.4 ±5.2 cm, and average

*Corresponding author. Yong Seon Lee (E-mail: hoy4124@hanmail.net)

weight was 65.3 ± 5.78 kg.

The three-dimensional kinematic and kinetic changes in the joints while walking were analyzed using a six-camera Vicon MX motion analysis system (Oxford Metrics Group, Oxford, UK) for the gait test of the subjects. Markers were placed on each of the subjects lower limbs in the standard places (Table 1). For analysis of gait, values of cadence (step/min), stride time (seconds), step time (seconds), step length (mm), stride length (mm), and ground reaction force were analyzed. A static test was conducted on the force plate in a stationary standing posture. For a dynamic test, the subjects were asked to walk 12 meters using the walking method more comfortable for them, that is, Nordic walking or walking; after they walked 12 meters more than 10 times, their most natural walking patterns were chosen three times and analyzed. To determine the pole length for Nordic walking, each subject's height was multiplied by 0.68.

The statistical analysis was carried out using a commercial statistics program, PASW Statistics for Windows Version 18.0 (SPSS, Chicago, IL, USA). All the data on the measured items were expressed as averages and standard deviations; to verify the differences in spatiotemporal parameters and ground reaction force, a paired t-test was performed. To verify the statistical significance of each result, the significance level α was set at 0.05.

Table 1. Marker location

Marker number	Location
1 and 2	Bilateral PSIS
3 and 4	Bilateral ASIS
5 and 6	Midway between the hip and knee, lateral surface of the thigh
7 and 8	Lateral femoral epicondyle
9 and 10	Midway between the knee and ankle, lateral surface of the shank
11 and 12	Lateral malleolus
13 and 14	Calcaneal tuberosity
15 and 16	Proximal to the second metatarsal head

ASIS: anterior superior iliac spine; PSIS: posterior superior iliac spine

Table 2. Comparison of spatiotemporal parameters for walking and Nordic walking

Characteristics	Walking	Nordic walking
Cadence (steps/min)	104.10±6.32	118.84±5.95***
Stride time (s)	1.16± 0.07	1.01±0.05***
Step time (s)	0.59±0.04	0.51±0.03***
Stride length (% LL)	1.30±0.15	1.42±0.10**
Step length (% LL)	0.70±0.08	0.72±0.06*

Values are shown as the mean±SD. *p<0.05; **p<0.01; ***p<0.001

Table 3. Comparison of vertical ground reaction force for walking and Nordic walking

	Walking	Nordic walking
Fz1 max	105.10±9.26	117.85±12.70**
Fz0 max	74.27±7.23	66.15±10.10**
Fz2 max	110.20±5.27	114.40±7.06*

Values are shown as the mean±SD. *p<0.05; **p<0.01. Unit: percent body weight

RESULTS

Comparison of the spatiotemporal gait parameters showed that cadence (118.84±5.95 steps/min vs. 104.10±6.32 steps/min), stride length (1.42±0.10 m vs. 1.30±0.15 m), and step length (0.72±0.06 m vs. 0.70±0.08 m) were increased and stride time (1.01±0.05 sec vs. 1.16± 0.07 sec) and step time (0.51±0.03 sec vs. 0.59±0.04 sec) were decreased for Nordic walking compared with walking, respecively (Table 2).

In the initial stance phase (Fz1), walking and Nordic walking showed ground reaction forces of 105.10±9.26% body weight (BW) and 117.85±12.70% BW, which were significantly different ($p < 0.01$). In the mid-stance phase (Fx0), walking and Nordic walking showed ground reaction forces of 74.27±7.23% BW and 66.15±10.10% BW, which were significantly different ($p < 0.01$). In the terminal stance phase (Fx2), walking and Nordic walking showed ground reaction forces of 110.20±5.27% BW and 114.40±7.06% BW, which were significantly different ($p < 0.05$) (Table 3).

DISCUSSION

This study was conducted to identify the effects of Nordic walking and walking on spatiotemporal parameters and ground reaction force, so that it would be possible to suggest an efficient means of walking for people who perform Nordic walking for health. Significant differences were in the spatiotemporal gait parameters between Nordic walking and walking. In Nordic walking, cadence, stride length, and step length were increased compared with walking, but stride time and step time were decreased. Strutzenberger et al. analyzed kinematic and kinetic data for Nordic walking collected from 16 subjects. They reported that the spatiotemporal parameters were remarkably increased during walking, the time of contact with the ground in Nordic walking was decreased, and cadence, step length, and stride length were obviously increased[8]. These correspond with the findings in this study.

In the present study, it is thought that weight dispersion decreased energy consumption and increased the walking speed due to use of the upper limbs in Nordic walking, though the propulsive force was adjusted in the lower limb muscles. It is also thought that the calf muscles improved the stability of the ankle joints[9] and promoted quick propulsion in the terminal stance phase during Nordic walking[10].

This study analyzed the changes in vertical ground reaction force in Nordic walking and walking. The results showed significant differences in the maximum force of the load reactor in the initial stance phase (Fz1) ($p < 0.01$) and in the terminal stance phase (Fz2) ($p < 0.05$). This corresponds with the results of previous studies reporting that the vertical ground reaction force ($p < 0.01$) and weight-bearing of the lower limbs decreased in Nordic walking[11, 12]. Using an electromyogram, force plate, and motion analysis system, Chiu and Wang analyzed the perceived exertion, muscle activity, and joint angle of the lower limbs and ground reaction force in 30 adults depending on changes in the velocity of walking. They found that walking speed had a clear effect on the vertical ground reaction force: the vertical reaction force was reduced due to increased walking speed in the mid-stance phase (Fz0), and the maximum force rose in the load reactor in the initial stance phase (Fz1) and the terminal stance phase (Fz2). Using of Nordic walking poles requires an increase in the force of the upper limb muscles to boost the weight-bearing of the body during the stance phase, improves balance and stability, and enhances the metabolism for movement[13].

This demonstrates that Nordic walking is more effective in improving functional capabilities by promoting effective energy use and reducing the lower limb load, as the weight of the upper and lower limbs is dispersed during Nordic walking. To apply Nordic walking as an exercise program, it is deemed more important to adjust the natural walking speed and weight-bearing of the body. In conclusion, further kinematic and muscular physiological research should be conducted after subjecting the Nordic walking subjects to a long-term training program, and a study on the effect of long-term Nordic walking on the elderly or people with a pathologic gait is needed in the future.

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