The Effects of Nordic Walking and Slope of the Ground on Lower Limb Muscle Activity

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Abstract

Psurny, M, Svoboda, Z, Janura, M, Kubonova, E, Bizovska, L, Martinez Lemos, RI, and Abrantes, J. The effects of Nordic walking and slope of the ground on lower limb muscle activity. *J Strength Cond Res* 32(1): 217–222, 2018—Nordic walking (NW) has proven to be a simple and safe mode of exercise that can be used in various types of sport, recreation, and rehabilitation activities. The aim of this study was to assess the effect of Nordic walking and slope of the ground on lower limb muscle activity. The experimental group consisted of 22 healthy men (aged 22.8 ± 1.4 years). The subjects walked on a treadmill at a self-selected speed. Two walking conditions (NW and walking) and 2 ground slopes (level ground and uphill walking at an 8% incline) were used. The surface electromyographic signals of the gastrocnemius lateralis, tibialis anterior, vastus medialis, rectus femoris, biceps femoris and gluteus medius were recorded. Nordic walking resulted in increased activity of some lower limb muscles, particularly during the first half of the stance phase, and decreased muscle activity during the first half of the swing phase. Uphill walking elicited increased muscle activity compared with level walking, particularly during the stance phase and the second half of the swing phase during both walking and NW, and the change was more pronounced during walking. We concluded that NW increased muscle activity in the lower extremities compared with walking, particularly on level ground. Increasing the ground slope enhanced the muscle activity to a much greater extent than NW.

Key Words electromyography, uphill walking, lower limbs, poles

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Introduction

Nordic walking (NW) is a modality of exercise involving the active use of a pair of specially designed poles that constrain the participant to a specific locomotion pattern with enhanced arm movement. Nordic walking is characterized as brisk walking with the additional use of poles that provide the advantage of actively involving the upper body (29). Nordic walking is presented as a safe and efficient exercise with numerous health benefits (16) and considered a suitable form of exercise for various types of sport, recreation, and rehabilitation activities (10,17).

Besides cardiovascular benefits, it has been shown that using NW as a training intervention induces positive changes in lower limb muscular strength (19) similar to brisk walking training programs (3). Accordingly, in specific scenarios, NW might be included in a continuum of exercises designed to enhance or maintain muscular strength, especially for geriatric populations or for individuals rehabilitating after a lower limb injury. For these reasons, a comprehensive elucidation of the muscular activity during NW is warranted.

A small number of studies have examined lower extremity muscular activity during NW and walking; however, the findings have been equivocal. Sugiyama et al. (28) reported that NW reduces muscle activity in the lower extremities during the push-off phase. By contrast, however, Shim et al. (24) found that NW had no effect on lower extremity muscle activation. Based on these conflicting findings and the apparent differential loading of the lower extremities for the heel-strike versus push-off phases (7,11), further clarification is needed.

Because NW is typically performed in outdoor settings and alterations in terrain would likely change the nature of the training stimulus, understanding the effect of different ground slopes during NW would be beneficial. It has been demonstrated that lower extremity muscle recruitment strategies and the amplitudes associated with muscle activity are influenced by walking speed (2,6,9,27) and the slope of the ground (9,15). The major difference between uphill and level walking is that the knee is flexed when the lead foot lands during uphill walking, but it is nearly extended at an analogous time during horizontal walking. Therefore, individuals cannot take advantage of the energy conservation that occurs in horizontal walking (5). During uphill walking, the activation of the hip and ankle extensor muscles is increased (9,15), and these changes occur progressively with steeper grades (9).

The aim of this study was to assess the effect of NW and slope of the ground on lower limb muscle activity.

Methods

Experimental Approach to the Problem

This cross-sectional study was performed in the university laboratory for exercise physiology. The hypothetical presumption was that NW and slope of the ground influence muscle activity of the lower limbs. This information is important when we consider NW as a training modality.

Subjects

The experimental group included 22 healthy men (Mean +/− SD aged 22.8 ± 1.4 years [range 20–25 years], height 1.80 ± 0.05 m, mass 75.0 ± 4.7 kg) who had no experience with NW before the start of this research. All participants were fully informed about the study procedures and possible risks of their participation in the study. The subjects voluntarily participated in the study after they provided written consent. The study was approved by the Institutional Review Board of the Faculty of Physical Culture, Palacky University Olomouc.

Procedures

Our study used a comparative design. Before data collection, all participants were introduced to the basic principles of NW. The participants then underwent two 1-hour training lectures with a NW lecturer. The lengths of the poles for each participant were set at 68% of the total body height (12). Walking speeds were determined by each participant.

Each participant was asked to perform NW the length of a 40-m track at a self-selected speed. The walking speed was measured using photocells. The photocells were placed 20 and 30 m from the start of the track. The self-selected NW speed was measured twice, and the mean of the 2 speeds was calculated. The NW track speed was used to set individual treadmill speeds (it was considered as self-selected speed) for both walk and NW on a treadmill.

Before commencing the main part measurement, all participants were familiarized with walking and NW on a treadmill. The participants were asked to get sufficient sleep before the measurements and to avoid intense exercise and the consumption of alcohol for 24 hours before the experiment. The participants did not eat a meal for 2 hours before the measurements.

The protocol on the treadmill consisted of 12 conditions. Both regular walking and NW was assessed during both level and incline (8%) walking at 3 speeds (self-selected, increased by approximately 10%, and increased by approximately 20%). For this study, only walking at the self-selected speed was analyzed based on the study focus of the effects of NW and the ground slope.

The NW and walking protocols lasted 7 minutes each. The sequence of the protocols was random for each participant, and the sequence of conditions in each protocol was also randomized to avoid the influences of adaptation to the walking performance and fatigue. At the beginning of each protocol, the subjects warmed up for 30 seconds at the same speed and slope used in the first condition to acclimate participants to the walking performance. Subsequently, each condition lasted 1 minute. The muscle activities were measured during the second 30 seconds of each condition. The first half (30 seconds) served as a period of adaptation to the new condition. The slope was altered only once during the entire protocol, specifically, in the middle of the protocol. The changes from a 0 to an 8% incline and vice versa lasted approximately 27 seconds; therefore, an extra 30 seconds were inserted into the middle of the protocol. At the end of the protocol, the speed of the treadmill slowed to 2 $km \cdot h^{-1}$ to allow the participants to cool down. All measurements were performed under standard laboratory conditions. The subjects wore common sport shoes for the walking activities.

Instrumentation

This study was performed using a special ergometer LODE Valiant treadmill with a 2-m-wide belt (Lode, B. V. Medical Technology, Groningen, the Netherlands) that enabled the subjects to perform the NW without any limitations of movement.

The surface electromyographic (EMG) signals from the m. gastrocnemius lateralis (GL), m. tibialis anterior (TA), m. vastus medialis (VM), m. rectus femoris (RF), m. biceps femoris (BF), and m. gluteus medius (GM) were recorded (Trigno Wireless System, Delsys Inc., Boston, MA, USA). Before the application of the surface electrodes, the skin was shaved and cleaned with abrasive skin prepping gel (Nuprep Skin Prep Gel; Weaver and Company, Aurora, CO, USA) to reduce skin impedance. Using adhesive tape, a skilled physiotherapist fixed all electrodes to the skin on the midpoint of the contracted muscle belly parallel to the muscle fibers.

Data Processing

Before processing, the data were automatically filtered with a 20- to 450-Hz bandpass filter in the acquisition software. The data were processed using a custom-written algorithm in MATLAB 2013a (MathWorks Inc., Natick, MA, USA). The filtered signal from each 30-second trial was full-wave rectified and divided into gait cycles according to the time intervals obtained using a camera (Sony DCR-TRV; Sony, Tokyo, Japan; frequency 50 Hz). Five gait cycles for each lower extremity were analyzed. Next, the EMG signals were normalized to the mean amplitude of a complete stride during the self-selected walking speed for the level ground condition for each limb separately (9). Using polynomial interpolation, the data for each stride were converted to 1,001 points, and each stride was divided into 4 phases as follows: the first half of the stance phase (ST1), the second half of the stance phase (ST2), the first half of the swing phase (SW1), and the second half of the swing phase (SW2) (14), such that the first half of the stance phase and the second half of the swing phase represented movement braking, and the second half of the stance phase and the first half of the swing phase represented movement acceleration. The mean amplitudes were computed within each of the phases. The amplitudes from the left and right lower extremities were averaged.

Statistical Analyses

The acquired data were processed using the STATISTICA program (version 10.0; StatSoft, Inc., Tulsa, OK, USA).

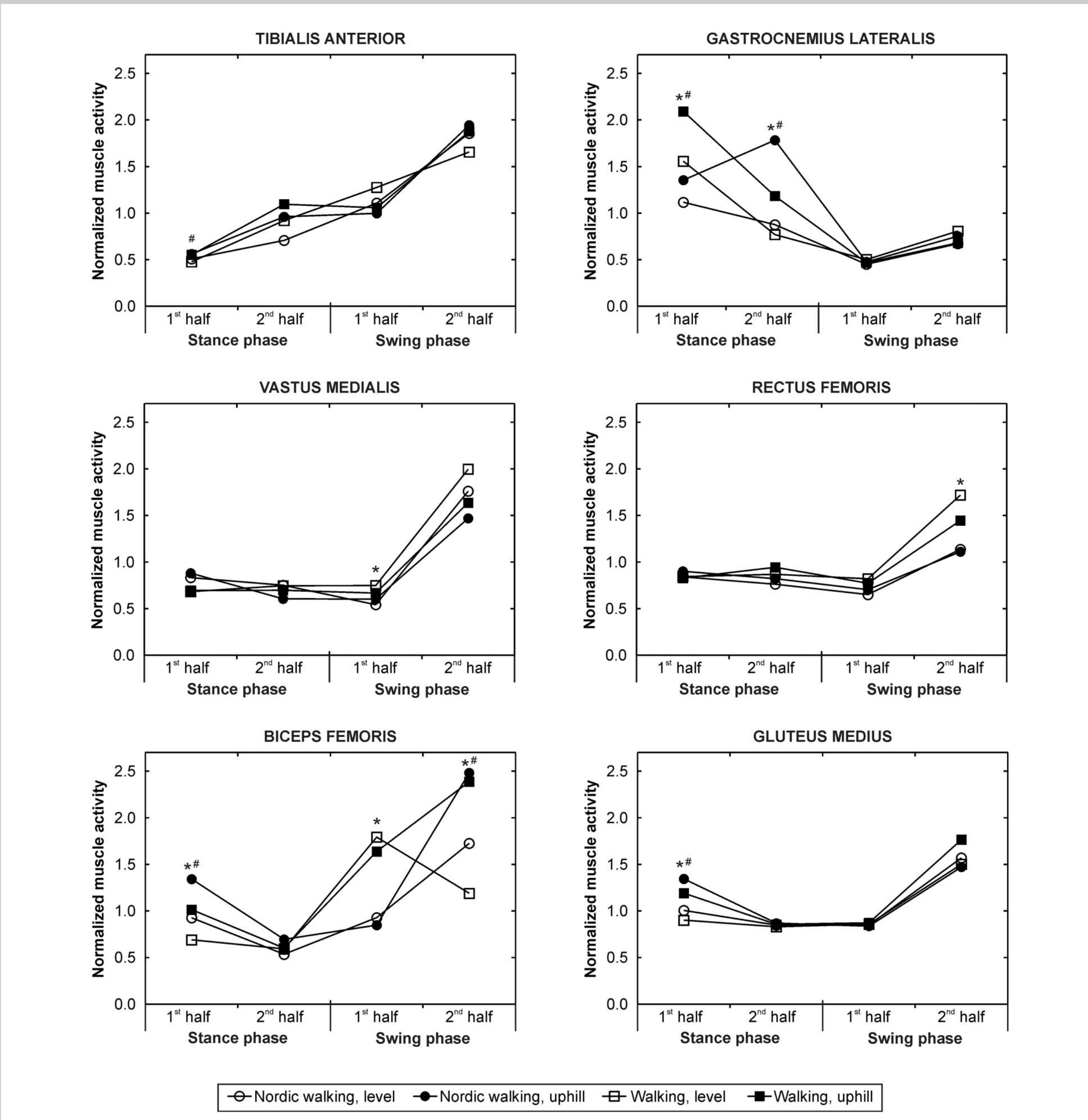

Figure 1. The medians of 5 cycles of electromyographic signals from selected muscles during Nordic walking and walking normalized to the mean amplitudes during a complete stride during the self-selected walking speed for the level ground condition. *Significant effect of walking; #significant effect of the ground slope.

Kolmogorov-Smirnov tests revealed nonnormal distributions of the data, thus the effects of slope and walking condition were assessed using the Kruskal-Wallis analysis of variance. The level of statistical significance was set at $\alpha = 0.05$.

Results

The results revealed that the pattern of locomotion (walking vs. NW) and the ground slope influenced the muscle activity of the lower limbs. Significant differences were found in all phases of the gait cycle.

Effects of Nordic Walking

The EMG data recorded from all muscles except the TA exhibited significant differences between NW and walking (Figure 1). Regarding the GL, NW resulted in a decrease in muscle activity during ST1 ($p < 0.001$) and in an increase in muscle activity during ST2 ($p = 0.014$). Compared with walking, NW resulted in a significant decrease in the muscle activity of the VM during SW1 ($p = 0.007$) and the RF muscle activity decreased during SW2 ($p = 0.005$). Nordic walking significantly influenced the activity of the BF muscle as indicated by an increase during ST1 ($p = 0.002$), a decrease during SW1 ($p < 0.001$), and an increase during SW2 ($p = 0.014$). Regarding the GM, NW caused an increase of muscle activity during ST1 ($p = 0.029$). In the other muscles and phases, NW did not significantly affect muscle activity.

Influence of the Ground Slope

Electromyographic activity increased for the TA, GL, BF, and GM when changing from level to uphill walking, regardless of speed and walking conditions (Figure 1). It also increased during ST1 for the TA ($p = 0.048$), GL ($p = 0.007$), BF ($p = 0.001$), and GM ($p = 0.001$) when changing from level to uphill walking. Finally, EMG activity increased during ST2 for the GL ($p = 0.001$) and during SW2 for the BF ($p = 0.001$) when slope was increased.

Discussion

The purpose of this study was to quantify the activity of the muscles of the lower extremities during walking and NW on level ground and on an incline (uphill) in healthy people.

Although some studies have investigated muscle activity during NW, it remains unclear whether proper NW technique was used and sufficient time was allowed for technique familiarization. According to Hansen et al. (13), some scientific studies used NW novices and introduced the poles and technique on the day of the investigation, which very likely biased the results. Shim et al. (24) reported that these factors could have contributed to the lack of any differences observed between NW and walking. Proper technique plays an important role in NW (11,13,25). The backward pole position during the loading phase is important because if the backward pole position is missing (i.e., if the tips of the poles are placed in front of the walker), trekking pole technique is being used. The purpose of the trekking pole technique is to increase balance and stability, whereas NW is considered fitness walking. A handful of studies (4,8,26,30) that focused on the loading of the lower extremities during hiking or trekking have concluded that the use of poles during walking reduces the loading of the lower extremities. It is important to focus on correct NW technique and to work with subjects experienced in NW during scientific studies because using incorrect poling technique can affect the results. It is necessary to avoid confusion between NW technique and other poling techniques.

During the first half of the stance phase in NW, activity of the BF and GM increased, GL activity decreased. The increased BF activity was most likely associated with increased knee control demands. During the loading response, the BF acts as a knee flexor and protects the knee against hyperextension (22). Increased movement control demands during NW could be associated with higher loading rates and horizontal forces as well as greater pronation and pronation velocity compared with walking (11). The potential of the hamstrings to generate support during the loading response was confirmed by Anderson and Pandy (1). The activity of the GM during the first half of the stance phase enhances hip stability in response to the contralateral movement of the pelvis (22). Thus, our results suggest that NW is associated with increased hip stabilization demands because of more active movement performance. During the first half of the stance phase, the GL slows forward progression by decelerating the forward movement of the trunk (18); thus, our results demonstrated that the requirements for trunk deceleration during NW are decreased relative to walking.

During the second half of the stance phase, a significant difference in muscle activity between walking and NW were found only for the GL (increased in NW). In this phase, the function of the GL is to lock the ankle so that the forefoot serves as the point of rotation (20,22). Thus, our results suggest that ankle locking during active push off is more demanding during NW.

The first half of the swing phase during NW was characterized by decreased muscle activity of the BF and VM. This decreased muscle activity may have occurred because of a greater extension of the hip joint during NW when the hip flexor's elasticity and gravity help to move the trailing leg (21).

During the second half of the swing phase, the activity of the BF increased and the activity of the RF decreased during NW compared with walking. During this phase, the BF begins its action in preparation for the initial contact to prevent excessive hyperextension. This finding is consistent with the results observed during the first half of the stance phase. The activity of the RF is associated with knee extension. Our results suggest that knee extension during the swing phase is more passive in NW.

In the scientific literature, we found only 3 studies that compared muscle activity between walking and NW. Shim et al. (24) did not find any significant differences in the activities of the RF, BF (lateral head), TA, or GL. Pellegrini et al. (21) observed a significant decrease in the GL activity during NW compared with walking in both level and uphill conditions. Sugiyama et al. (28) observed differences in muscle activity between walking and NW at various gait speeds. The activity of the m. vastus lateralis at all velocities and the activity of the GL at nearly all velocities were decreased during NW. The activity of the BF was reduced during NW only at high velocities. The activity of the TA did not exhibit any significant difference between walking and NW. Although this study assessed activity during the entire gait cycle, the results of these other studies regarding the GL and the TA are comparable. Findings concerning the BF were different when comparing our study with other studies.

Pellegrini et al. (21) observed increased muscle activity in 5 lower-body muscles, i.e., the GL, TA, VM, BF, and GM. They suggested that the additional work of climbing against gravity during NW seemed to be performed by the lower extremities rather than the upper extremities, and this suggestion is in agreement with the findings in a study by Pšurný et al. (23) in which no increase in the force exerted through the poles was found during uphill NW.

In our study, the effects of the slope were also assessed during both walking and NW conditions. Level walking was compared with uphill walking on a slope of 8% (approximately 4.6°). Particularly during the stance phase, it could be expected that the activity of most of the lower limb muscles would increase with increases in the incline. Franz and Kram (9) observed significant increases in the activity of the m. gluteus maximus, BF, VM, and m. soleus at grades steeper than 3 degrees and for the RF at grades steeper than 6 degrees. In this study, we compared the muscle activity during each of the halves of the stance and swing phases.

During the first half of the stance phase, increased muscle activity during uphill walking were observed in the GL, TA, BF, and GM during both walking and NW. During uphill walking, immediately after the initial contact, greater plantar flexion is necessary, and plantar flexor (GL) activity would thus be expected. In addition, this muscle slows forward progression by decelerating the forward motion of the trunk (18). The increased activities of the other muscles (i.e., the TA, BF, and GM) are suggestive of an increased need for support between the heel-strike and the flat-foot phase (1,22).

During the second half of the stance phase, increased muscle activity was observed in the GL. According to published studies (20,22), during this phase the GL has the greatest activity. The function of the GL is to lock the ankle so that the forefoot serves as the point of rotation. Our results demonstrated that during uphill walking, this mechanism was more demanding than during level walking.

In the swing phase, we found only 1 significant effect of the ground slope. In the second half of the swing phase, we observed increased muscle activity in the BF during uphill walking. Increased muscle activity during this phase is usually associated with preparation for the next initial contact and loading response. Preparations are initiated in the BF to prevent excessive hyperextension (22).

Practical Applications

The results of this study are important for instructors of NW as well as for fitness and health care professionals involved in strength training and rehabilitation. These results allow them to assess the effect of NW and slope of the ground on lower limb muscle activity.

Some studies suggest that the muscle activity in the lower extremities during NW is reduced; however, these studies usually relate to muscle activity across whole gait cycles. Our study showed that the effect of NW is different in various phases of the gait cycle.

In NW, a more active gait pattern is typical. In the first part of the stance, phase activity is related to increased knee control demands, similar as to the increased demands of hip stabilization in response to the contralateral movement of the pelvis. Stabilization of the foot during the stance phase is more demanding during NW. Conversely, NW results in decreased requirements of trunk deceleration. This information can be useful when NW is used in the training process or rehabilitation settings.

For training purposes, the addition of the slope effect seems to be suitable regardless of type of walking (walking, NW). It could be expected that the activity of most of the lower limb muscles increase with the slope of the ground. Our results demonstrated that stabilization of the foot and plantar flexion during take-off is more demanding during uphill walking compared with level walking. The increase in the slope of the ground increased the muscle activity of the lower extremities to a much greater extent than NW.

It is also important to focus on proper NW technique. It seems that incorrect NW performance results in a decrease in activity of the muscles of the lower limbs muscle activity, thus appropriate familiarization of NW technique before training or rehabilitation sessions is necessary.

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