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Original Article

Effects of the height of shoe heels on muscle activation of cervical and lumbar spine in healthy women

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Abstract. [Purpose] The purpose of this study was to investigate the effects of different height of high heels on muscle activation of the paraspinalis cervicis and erector spinae in healthy young women. [Subjects and Methods] Thirteen healthy women were recruited in this study. To examine the effects of different heights of heels on muscle activation, the paraspinalis cervicis (cervical spine) and erector spinae (lumbar spine) were measured at the time of heel strike and toe off during gait on three different conditions (barefoot, 4 cm high heels, and 10 cm high heels). There are no previous trials or reports that have evaluated this approach in patients with chronic neck pain. [Results] A significant increase in muscle activation of the paraspinalis cervicis and erector spinae at heel strike and toe off (except that of the paraspinalis cervicis at toe off in healthy subjects) was observed in the under 10 cm high heel condition as, compared to that with barefoot condition, in all the subjects. [Conclusion] The height of the high heels affects to the activation demand of the paraspinalis cervicis and erector spinae in patients with neck pain.
Key words: Erector spinae, High-heel shoes, Neck pain

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INTRODUCTION

Women have relatively weak neck muscles, which can be a primary cause of chronic fatigue syndrome related to the muscular system, resulting in higher risk of chronic neck pain[1)]. In relation to pain a study by Fisher found that 62% of women wear heels that are over 5 cm, and the ones who enjoy wearing high heels are reported to suffer from foot, knee, and back pain, as well as an alteration of the normal gait patterns[2)]. According to previous studies, wearing high-heeled footwear can alter the static posture and dynamic movements of the body, and is regarded as a cause of musculoskeletal problems related to the spine[3–5)]. Walking in high-heeled shoes changes the kinetic characteristics of the lower extremity joints, causing a reduction in ankle plantar flexor muscle moment, and power during stance phase and increases in forefoot peak pressure. Walking in high heels produces an upward displacement of the center of mass of the body and possibly a more unstable posture compared to that producted by low-heeled walking[6–9)]. Additionally, shock and ground reaction forces can lead to increased axial pressure onto the intervertebral discs, resulting in increased erector spinal muscle activation[10)]. Walking in high-heeled shoes produce an increase in the ground reaction force compared to flat heeled shoes. In theory, the increase in ground reaction force with increased height may result from decreased subtalar joint pronation at heel strike and a lengthened tibiofemoral lever arm. As a result, trunk muscle activity increases with increasing heel height, which changes the posture and ground reaction force, leading to discomfort of the back muscle in women who wear high heels[11)]. In addition, the effects are magnified with increased activation of the erector spinae muscles, which contribute to compression of the spine. Therefore,

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wearing high heels for an extended period can lead to an increase in paraspinal musculature activation of the lumbar and cervical spine, causing prolonged overload and fatigue in the trunk and neck muscles[1].

A recent study reported that walking in heels induced a significant increase in the activation of cervical muscles in healthy subjects. However, research on the influence of wearing high heels is still insufficient. This study was conducted in order to examine the effects of wearing high heels during gait on the cervical and lumbar musculature in patients with chronic neck pain and in healthy women.

SUBJECTS AND METHODS

Thirteen healthy women were recruited for this study. An information leaflet describing the study method and procedure was used for the recruitment of subjects. The inclusion criteria for patients were as follows: (1) history of neck pain for the past three months or less, (2) between the age of 20–45 years, (3) not experiencing orthopedic or neurological problems other than neck pain, and (4) able to wear high heels without pain. This study excluded subjects who felt acute worsening of pain symptoms during their maximal effort or who were in an unstable condition with an acute flare up during the time of testing. All participants agreed to participate and signed the consent form. The study was approved by the local institutional review board. Table 1 shows a list of common characteristic of the participants in this study. A test on the general characteristics of the subjects was filled out prior to conduct of this study. To determine the effects of the different heights of heels on the muscle activation, the paraspinalis cervicis (cervical spine) and erector spinae (lumbar spine) were measured at the time of heel strike and toe off during gait. After preparing the skin by shaving, cleaning with alcohol, and sanding, two differential surface electrodes were placed at a distance of 2 cm from each other. Surface electromyography (EMG) electrodes were placed on the paraspinalis cervicis and erector spinae of the subjects' dominant side. All electrodes were placed over the muscle mass, which was visible during maximally resisted voluntary contraction. Two foot switches were placed and attached on the shoe exterior, underneath the first metatarsal head area and the heel of the shoe on the dominant side.

To familiarize the subjects to the testing condition with surface electromyography (EMG) attached to their body, they were instructed to walk down the walkway three times prior to the testing condition. Each subject was instructed to walk naturally at a self-selected velocity on a flat and even surface under three different testing conditions (barefoot, 4 cm stiletto heels, and 10 cm stiletto heels with a base of 1 cm^2). Each condition was randomly selected and was repeated three times. Prior to each gait trial, subjects were instructed to stand still with their feet together in a comfortable position, and then were asked to look straight up and walk down the 10 m walkway in front of them. To prevent muscular fatigue, a one-minute break was given after three measurements. Among the surface EMG data collected during the 10 m walk, the data during the middle 6 m block was used for analysis. Data from the three trials were averaged for analysis using the heel strike and toe off events for each gait trial. All subjects with neck pain were in a stable condition without an acute flare up during the time of testing.

Differences in the EMG activity of the paraspinalis cervicis and erector spinae in patients with neck pain during heel strike and toe off during gait were assessed using the SPSS 12.0 Program (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was conducted to ensure that the variables were normally distributed. A one-way repeated ANOVA was used for the identification of significant differences among the barefoot, 4 cm high heel, and 10 cm high heel conditions; and a post-hoc test using the least-significant-difference (LSD) method was employed for comparing the conditions. Statistical significance was set to $p<0.05$.

RESULTS

Muscle activation in the paraspinalis cervicis and erector spinae at heel strike and toe off (except that of paraspinalis cervicis at toe off event) differed significantly with the 10 cm high heels, compared to the barefoot condition. At heel strike, muscle activation of the paraspinalis cervicis was significantly greater with the 10 cm high heels as compared to that with the 4 cm high heels (Table 2).

DISCUSSION

This study demonstrated the effects of walking in high heels on the muscular activity of the cervical and lumbar muscles in healthy women. Previous studies have reported the muscle activation or biomechanical effects of walking in high heels in healthy women. Mika and coworkers studied the effects of walking on barefoot, 4 cm high heels, and 10 cm high heels on the activation of the cervical paraspinalis in young women (20–25 years) and older women (45–55 years). The results showed a significant increase in cervical muscle activation while walking in 10 cm high heels. Subjects in the older group showed a significant increase in the cervical muscle activation at heel strike while walking in 4 cm high heels and 10 cm high heels. A higher magnitude of vertical ground reaction force was demonstrated with high heels, and the effects were amplified with the presence of more active erector spinae muscles, which could act partially to compress the spine[12, 13].

Results of previous studies have demonstrated an increase in the compensated muscular activities with an increasing heel height. Wearing high heels changes the overall body posture and loading on the spine and the joints in the lower extremities,

Table 1. Demographic data of the collective intention to treat (N=13)

Variable	Mean±standard deviation
Age (yrs)	31.5±6.6
Height (cm)	161.1±4.2
Body mass (kg)	55.1±7.5

Table 2. Muscle activation (%MVIC) in normal subjects under the three conditions (N = 13)

Muscles	Gait cycle	Barefoot	4 cm high-heeled	10 cm high-heeled
Cervical paraspinae	Heel strike	7.6±2.1[a]	7.7±2.4	9.4±3.2*†
	Toe off	7.5±1.8	7.1±1.6	8.2±2.5
Erector spinae	Heel strike	24.7±8.2	29.5±10.5	31.2±12.3*
	Toe off	28.3±10.5	30.3±11.1	36.2±18.3*

[a]Mean±SD
%MVIC: %maximum voluntary isometric contraction
*Significant differences compared to barefoot condition
†Significant differences compared to 4 cm high-heeled condition

resulting in a change in the body's center of mass (COM). Snow and Williams reported that wearing excessively high heels induces a shift in the body's COM anteriorly and superiorly. Ankle is shifted superiorly and anteriorly, and the base of support (BOS) shifts anteriorly. As the body tries to maintain this posture without falling, compensatory activity of both the erector spinae and the cervical paraspinalis increases[14]. Cervical spine movement assists in maintaining the head stability in space, assists in dynamic postural control, and compensates for trunk motion to maintain head stability during gait. With neck extension, the center of mass of the head is moved posteriorly, thereby maintaining the head position above the trunk. Neck extension may also assist in balancing the head over the trunk due to the center of mass of the head lying anterior to the cervical spine.

Previous studies also attempted to determine the lumbar curve angle, center of mass, and activation of the erector spinae during the gait of healthy women wearing high-heeled shoes[6, 15]. The results indicated a significant decrease in the lumbar curve angle and, in the vertical movement of the body's center of mass, and a significant increase in activation of the erector spinae. Our results showed a significant increase in muscle activation of the erector spinae at heel strike and toe-off events while wearing 10 cm high heel, as compared to that in barefoot condition in all subjects.

The results of our study demonstrated that wearing high-heeled shoes increases the activation of cervical and lumbar musculature in healthy women[16]. According to Mika and colleagues, even healthy people wearing high-heeled shoes experience increased back muscle activity during gait, which could promote local muscle fatigue, in turn leading to tissue deformation, such as swelling or decreased movement[13]. In addition, these symptoms may be more remarkable while wearing stiletto type high heels with unstable balance.

This study investigated only the immediate effects of wearing high heels on walking. Further studies are needed to evaluate the long-term effects between high-heeled shoes and the mechanism of muscle activation of the cervical and lumbar spine. Another limitation of this study was the small number of recruited subjects. For a more accurate observation of the relationship between neck pain and high-heeled shoes, a follow-up study with a longer period of time and a larger experimental group should be conducted. Future studies will be necessary to evaluate the effect of high-heels on cervical spine kinematics and muscle fatigue over an extended period of time. In addition, consideration of changes in body alignment and muscle activation caused by extrinsic factors, such as high-heeled shoes, may be a more effective approach for planning treatment strategies.

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