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Original Article

Muscle activation of paraspinal muscles in different types of high heels during standing

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Abstract. [Purpose] This study researched the effects of different types of high heels on the muscles surrounding the cervical spine, the thoracic spine, and the lumbar spine by analyzing muscle activation of the paraspinal muscles during standing while wearing high heels. The high heels were all of the same height: 8 cm. [Subjects and Methods] The 28 subjects in this experiment were females in their 20s with a foot size of 225–230 mm and a normal gait pattern. To measure the muscle activation of the paraspinal muscles, EMG electrodes were attached on the paraspinal muscles around C6, T7, and L5. The muscle activation during standing while wearing 8-cm-high wedge heels, setback heels, and French heels was then measured. The measurements were performed 3 times each, and the mean value was used for analysis. [Results] The levels of muscle activation of the paraspinal muscles induced by standing on wedge heels, setback heels, and French heels in the cervical and lumbar areas were significantly higher than those induced by standing on bare feet. But there was no significant difference according to the heel types. [Conclusion] The height of the heels presented a greater variable than the width of the heels on the muscle activation of paraspinal muscles. Therefore, wearing high heels is not recommended for those who have pain or functional problems in the cervical and/or lumbar spine.

Key words: Heel type, Paraspinal muscle, Muscle activation

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INTRODUCTION

The original purpose of shoes was for safety and comfort of the foot during walking, so in earlier eras of the shoe industry, the primary emphasis was placed on the functional aspects of shoes[1)]. However, these days, high heels are preferred for fashion, to increase height, or to follow modern trends[2)]. Hence 59% of women wearing high heels wear them for 1 to 8 hours per day[3)]. Some women wear them for more than 10 hours continuously per day[4)].

As a result, the original function of shoes to protect the foot from the rough surface of the ground, weather, and the environment, and to increase the efficiency of walking has now been replaced by the aesthetic effect of high heeled shoes. But high heeled shoes have a lot of bad effects on the body. High heels can often cause ankle sprains and back and lower extremity pain. They also cause shortening of the Achilles tendon, an increase in oxygen consumption, and a decrease in stride length and gait velocity. It is also reported that high heels change the joint mobility of the knees, which can cause degenerative arthritis[5)]. Because the contact surface of high heels on the ground is small, instability of the ankle is increased and the position sense is decreased. Therefore, high heels can cause joint problems[6)]. In addition, high heels with a narrow shoe toe can cause foot deformity and back pain[7)] and can be a factor in increasing lumbar lordosis[8)]. Furthermore, wearing high heels for an extended period can cause the head and thoracic vertebrae to move towards the back and can reduce the lordosis and pelvic tilting muscles[9)]. Wearing high heels can also sometimes cause abnormal function of the paraspinal muscles. In this regard, Lee et al.[10)] studied the effect of high heels on the paraspinal muscles of healthy persons. He reported that increasing the height of heels causes an increase in the EMG amplitude in the back extensor. He also reported that the height of heels has an influence on the tension of the paraspinal muscles. On the other hand, Lee and Jeong[4)] stated that even when heel heights are the same, different types of heels can have different heel surfaces contacting the ground. Therefore, stability and comfort can differ according to the type of heel attached to the shoe, causing varying effects on the human body.

Nevertheless, the previous studies on the effects of types of high heels on the cervical, thoracic, and lumbar paraspinal muscles are insufficient. Therefore, this study researched the effects of different types of high heels (specifically the wedge heel, setback heel, and French heel, all at a height of 8cmfor consistency), on the muscles surrounding the cervical spine, the thoracic spine, and the lumbar spine.

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SUBJECTS AND METHODS

All twenty-eight participants were healthy females (19.2±1.1 years, 159.6±2.962 cm) without any previous history of foot deformities, abnormal gait pattern, or musculoskeletal diseases for the previous 5 years. They had foot sizes between 225–230 mm. They were informed of the purpose of this study and joined voluntarily. This study complied with the ethical standards of the Declaration of Helsinki, and written informed consent was received from each participant.

Generally, high heels are available in various heights and forms according to personal preference or style. The high heels commonly found now in stores include French heels, stacked heels, continental heels, setback heels, Cuban heels, pantaloon heels, angle heels, Dutch heels, flat heels, and wedge heels[11]. In this study, we selected 3 types of high heels that were different in shape and function. Those selected for the study were wedge heels, setback heels, and French heels.

To measure the muscle activations of the paraspinal muscle surrounding the cervical spine, the thoracic spine, and the lumbar spine during standing while wearing high heels, an EMG unit (Keypoint, Medtronic, USA) was used. To reduce measurement errors, the contact points for the electrodes were shaved and cleansed with alcohol. In addition, the connecting wires were firmly attached to the bodies of the participants so that noise would not interfere with the EMG signals[12]. The root mean square (RMS) was used to examine the value of muscle activation. The following muscles were selected to measure the paraspinal muscle activation: the paraspinal muscle around C6 of the cervical spine, the paraspinal muscle around T7 of the thoracic spine, and the paraspinal muscle around L5 of the lumbar spine.

After attaching EMG electrodes to the paraspinal muscles and waiting for the subject's breathing rate to stabilize, the muscle activation of each muscle was measured while the subject stood on the ground with bare feet. Subsequently, muscle activation during standing while wearing 8-cm-high wedge heels, setback heels, and French heels was measured. Muscle activation was measured 3 times, and the mean value was used for analysis. In this study, repeated measure ANOVA was used to examine the effects of types of heels on the paraspinal muscle activation. We also carried out the paired t-test in order to examine differences in the values of muscle activation between each type of heel. We used the SPSS for windows software (ver.21) for statistical analysis and a significance level of α=0.05.

RESULTS

The muscle activation of the C6 paraspinal muscle in the standing position differed significantly with each type of heel ($p<0.05$). With bare feet, the value was 146.3 μV; with wedge heels, it was 187.1 μV; with setback heels, it was 202.6 μV; and with French heels, it was 201.2 μV. The levels of muscle activation of the paraspinal muscle induced by wedge heels ($p<0.05$), setback heels ($p<0.05$), and French heels ($p<0.05$) were higher than that induced by bare feet. But no difference was demonstrated among wedge heels, setback heels, and French heels. In the T7 paraspinal muscle, the muscle activation with bare feet was 135.3 μV; with wedge heels, it was 138.3 μV; with setback heels, it was 167.7 μV; and with French heels, it was 162.3 μV. Although it initially might appear that the levels of muscle activation induced by setback heels and French heels were higher than those induced by bare feet and wedge heels, there was actually no statistical difference. The muscle activation of the L5 paraspinal muscle differed significantly with the type of heels ($p<0.05$). With bare feet, it was 206.9 μV; with wedge heels, it was 265.5 μV; with setback heels, it was 310.6 μV; and with French heels, it was 292.3 μV. The levels of muscle activation of the paraspinal muscle induced by wedge heels ($p<0.05$), setback heels ($p<0.05$), and French heels ($p<0.05$) were higher than that induced by bare feet. But no difference was demonstrated among wedge heels, setback heels, and French heels (Table 1).

Table 1. Muscle activation of paraspinal muscles in subjects wearing different types of high heels during standing (unit: μV)

	Barefoot	Wedge heel	Setback heel	French heel
Cervical*	146.3±92.33	187.1±95.3[a]	202.6±132.5[b]	201.2±132.6[c]
Thoracic	135.3±91.7	138.3±119.6	167.7±128.9	162.3±117.7
Lumbar*	206.9±174.0	265.5±168.7[a]	310.6±220.7[b]	292.3±207.7[c]

*$p<0.05$
[a]Bare foot<wedge heel, [b]bare foot<setback heel, [c]bare foot<french heel by paired t-test ($p<0.05$)

DISCUSSION

Various types of heels affect the stability and comfort of shoes. These days, shoes are available with various types of heels. Generally, the various types of high heels available in the market are classified by their function. Jeong[11] divided these heel types into categories and gave the following explanation: First of all, the French heel is shaped so that the front part of the heel is in the shape of Korean letter ㄱ. This shape provides a natural curve aligned with the bottom of the shoe. Since the bottom part of the shoe is connected to the heel like a tongue, it can reduce accidents caused by heel breakage or by coming out of alignment with the back of the shoe. The stacked heel generally consists of several layers of leather 5 mm thick stacked together and trimmed to match the shape of the heel. The continental heel is usually 3–4 cm high. The special characteristic of this heel is that the upper part of the chest of the heel spreads somewhat towards the center of the shoe. The setback heel looks similar to the continental heel, but the surface of the back of the heel is straight, forming a right angle. The Cuban heel is similar to the continental heel and is generally found in medium heights, but it is not curved like the continental heel. The pantaloon heel is similar to pantaloon pants: the top lift part of the heel is spread out as it extends to the bottom part of the heel, and the waist line of the heel is curves inward naturally. Regarding the angle heel, the surface of the base of the heel is straight until reaching the waist line, and it looks like the shape of Korean letter ㄱ. Dutch heeled

and French heeled shoes with a reduced height are called low heel shoes. Flat-heeled shoes are considerably flatter. They are usually worn by students or as casual shoes; their heights vary from 1 cm to 3 cm, and they are available in different forms. The wedge heel appears triangular when viewed from the side. Wedge heels run from the front of the shoe to the back but are thicker at the heels and narrower at the toes. They are usually worn with casual attire or semi-formal dress.

Due to the modern emphasis on aesthetics and fashion, high heels are made in many different forms. But as the height of the heel increases, the injury to the body also increases. Therefore, a number of research projects examining the effects of high heels on the human body have been performed. Hyun and Kim[13] researched the effects of high heels on the lumbar muscles by measuring muscle fatigue while wearing high heels of (4 cm, 6 cm, and 8 cm) and while wearing shoes without heels (0 cm). Their research has demonstrated that the fatigue of lumbar muscles was less serious when the heel was 4 cm high or less. However, a large increase in muscle fatigue was demonstrated when the heel was higher than 6 cm. Choi and Lee[14] stated that as the height of heels increases, body muscles tense to improve body balance, which in turn causes muscle fatigue and pain in the back, shoulder, and neck. In addition, Kim et al.[15] performed research on 28 females in their 20s with a foot size of 235–240 mm. Their research was performed to examine the change in muscle activation of cervical paraspinal muscles, thoracic muscles, and lumbar paraspinal muscles when walking while wearing functional walking shoes and high-heeled shoes. It demonstrated that the levels of muscle activation of cervical paraspinal muscles, thoracic paraspinal muscles, and lumbar paraspinal muscles were higher when wearing high heels than when wearing shoes with normal heels. Bullock-Saxton[16] mentioned that wearing high heels can change the local sensation in ankle joints, which in turn can cause changes in the feedback system of the central nervous system. These changes can interfere with the strength needed to adjust and adopt appropriate ankle movement, which can cause ankle problems. Opila et al.[17] stated that the higher the height of the heels and the narrower the surface area of heel that touches the ground, the greater the range of movement of center body mass (CBM) at the top, bottom, and sides. Some researchers have found that high, narrow heels can cause problems for ankle strategies. Resultant changes in hip strategy can also cause changes in paraspinal muscle activation. So Lee and Jeong[4] researched the effects of heel type (i.e. heel height and width) on the change in muscle activity of the lower extremities. Their research demonstrated that heel height affects the lumbar and lower extremity muscle activity, whereas the width of the heel does not affect it. Jeong[11] examined the change in the perpendicular direction of the CBM in regards to types of heels. The results showed that the height of the heel is a significant factor in the change in CBM. Meanwhile, the width of the heel is not a significant factor. Hence, summarizing all the results of the researches, we can conclude that height of the heel affects the range of movement of CBM which affects the paraspinal muscle activation, whereas the width of the heel has no effect on it.

For that reason we used high heels that were the same height but differed in contact width with the ground to research how they affect the paraspinal muscles. As a result, we could see an increase in muscle activation of the cervical and the lumbar paraspinal muscles when subjects wore the wedge heels, setback heels, and French heels. There were no other differences in the heels tested. Hence, we can conclude that heel height is a more significant factor than heel width when it comes to changes in the cervical, thoracic, and lumbar paraspinal muscle activation.

So, we recommend those who have pain or functional problems in the cervical and lumbar areas not wear high heels. However, because the study examined the change in paraspinal muscle activation during standing while wearing high heels, it does not reflect the effects of high heels when it comes to walking. The study also did not examine the change when walking or standing on slopes. So further research should be done on the use of high heels in subjects walking and standing on slopes.

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