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The Effects of Different Types of High Heels and Walking Velocity on Muscle Activation of the Paraspinal Muscles

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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 walking while wearing high heels. The high heels were all of the same height: 8cm.

METHODS: The 28 subjects in this experiment were females in their 20s with a foot size of 225-230mm. 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 walking while wearing 8cm high wedge heels, setback heels, and french heels was measured. The measurements were performed 3 times each and the mean value of the result was used for analysis. Two kinds of velocity were used in this study. One of the velocity was 2.5 m/s. The other was 3.5 m/s.

RESULTS: The muscle activation of paraspinal muscles increased significantly according to increase of walking

velocity. But there was no significant difference according to the heel types.

CONCLUSION: In view of the results, the height of heels and the velocity of walking are more convincing variables than the width of the heels on the muscle activation of paraspinal muscles. So wearing high heels is not recommended for those who have pain or functional problem of cervical and lumbar vertebrae.

Key Words: Heel type, Muscle activation, Paraspinal muscle, Walking velocity

I. Introduction

These day, high heels are preferred for the aspects of fashion, to seem taller or to follow the trends(Ko et al, 2008). In fact, the survey of the preference about high heels in Korea showed that female adults who are below 30 years old want to wear high heels that are higher than 7cm and they think much of the trend and fashion of the shoes (Choi and Chun, 1998). Further, in modern times wearing high heels which are higher than 10cm has been recognized essential condition to women who are at the forefront of trendy fashion because it highlights beauty

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of leg lines (Song et al, 2009). Hence 59% of women wearing high heels wear them for 1 to 8 hours per day(Yu et al, 2008). Some even wear them for more than 10 hours continuously per day(Lee and Jeong, 2002).

As a result, the original function of the shoes to protect the foot from rough surface of the ground, weather, the environment, and to increase the efficiency of walking has now been replaced by the aesthetic effect of high heels. But high heels give a lot of bad effects on the body. High heels can often cause ankle sprains, back and lower extremity pain. It also causes the shortening of achilles tendon, increase in oxygen consumption, decrease in stride length and walking velocity. It is also reported that it changes the joint mobility of the knees which causes the generative arthritis(Mika et al, 2011). Because the contact surface of high heels on the ground is small, the instability of ankle is increased and the position sense is decreased. Therefore, high heels can cause joint problems(Barrack et al, 1989). In addition, high heels with a narrow shoe toe can cause foot deformity and back pain(Choi and Lee, 2002a) and can be a factor in increasing lumbar lordosis(de Lateur et al, 1991). Furthermore, wearing high heels for a long time can cause the head and thoracic vertebrae to move towards the back and can reduce the lordosis and pelvic tilting muscles(Yoon et al, 2009). It can also sometimes cause abnormal function of paraspinal muscles.

In this regard, Lee et al(2001) studied the effect of high heels on paraspinal muscles of healthy person. He reported that increasing the height of the heels causes an increase in the EMG amplitude in the back extensor. This confirmed that the height of heels has an influence on the tension of paraspinal muscles. On the other hand, Lee and Jeong(2002) have stated that although the heel heights are the same, different types of the heels have different heel surface contacting the ground. So, these days, shoes are available with various types of heels. Jeong(2004) divided these heel types in to categories, and gave the following explanation: first of all, the 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 semiformal dress. The setback heel looks similar to the continental heel, but the back of the heel is straight down and forms a right angle. The french heel is shaped so that the front part of the heel is in shape of Korean letter. 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. 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 studies on the effects of types of high heels on cervical, thoracic, and lumbar paraspinal muscles are insufficient. Especially, the study which finds out the effects of velocity on the muscle activation of paraspinal muscles in wearing high heeled shoes is more insufficient. Therefore, this study researched the effects of different types of high heels during walking on the surrounding muscles of cervical, thoracic, and lumbar spine.

II. Methods

1. Subjects

All twenty-eight participants were healthy females without any previous history of foot deformities, abnormal gait pattern, or musculoskeletal diseases for the previous 5years. Their average ages were 19.2 ± 1.1 years and their average heights were 159.6 ± 2.9 cm. 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.

2. High heels

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(Jeong, 2004). 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(Fig 1), setback heels(Fig 2), and french heels(Fig 3).



Fig 1. Wedge Heels



Fig 2. Setback Heels



Fig 3. French Heels

3. Measurement of muscle activation

To measure the muscle activation of the paraspinal muscles 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(Fig 4). 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(Cho, 2007). The electrodes were 1.5cm×2.5cm disposable unipolar surface electrode. The sampling rate was fixed 1000Hz, 20-1000Hz was used for bandwidth, 50Hz was used for notch filter. The root mean square(RMS) was used to examine the value of muscle activation. RMS was used to examine the value of muscle activation. In relevant relation of RMS and muscle contractile force, if the muscle contractile force was higher then RMS was also higher. so we used the RMS value(Sohn et al, 1998). And in the muscle activation index that reflects the motor unit of muscle activity, it is most reliable and sensitive and reflects well the muscle contraction(Fisher, 1997).

As Jeong(2009) suggested, an EMG electrode was attached to the muscle belly where it is most activated. And Mika et al(2011) suggested that EMG electrode region was at a distance of 2cm away from the spine. The following muscles were selected to measure the muscle activation: the paraspinal muscles around C6 of the cervical spine, the paraspinal muscles around T7 of the thoracic spine, and the paraspinal muscles around L5 of the lumbar spine. Subsequently, muscle activation during standing and walking while wearing 8cm high wedge heels, setback heels, and french heels was measured. Through a preliminary walking test in treadmill, two kinds of walking velocity were selected for this study. One of the velocity was 2.5 ㎞/h and it felt comfortable and the other was 3.5 ㎞/h which felt fast. Treadmill(h/p Cosmos, Proxomed, Germany) was used for walking(Fig 5). Muscle activation was measured 3 times, and the mean value of result was used for analysis.

4. Statistical analysis

In this study, repeated measure ANOVA was used to examine the effects of types of heels on the paraspinal muscle activation. And repeated measure ANOVA was



Fig 4. EMG

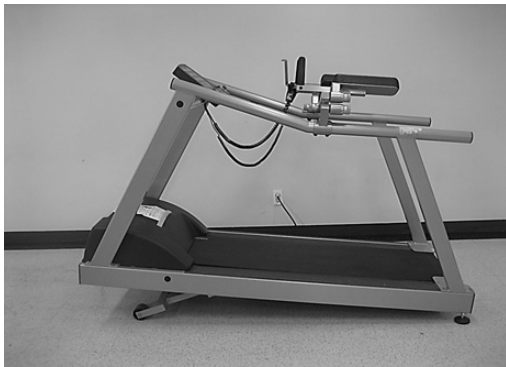


Fig 5. Treadmill

used to examine the effects of walking velocity on 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 SPSSWIN(ver.21) program for statistical analysis and a significance level of $\alpha = .05$.

III. Results

1. Muscle activation of cervical paraspinal muscles in different types of high heels and in different velocity

The muscle activation of the C6 paraspinal muscles in the standing position was no different significantly with each type of heel. With wedge heels, it was $187.14\mu V$; with setback heels, it was $202.56\mu V$; and with french heels, it was $201.20\mu V$. The muscle activation of the C6 paraspinal muscles in the slow walking was no different significantly with each type of heel. With wedge heels, it was $815.90\mu V$; with setback heels, it was $850.64\mu V$; and with french heels, it was $933.83\mu V$. The muscle activation of the C6 paraspinal muscles in the fast walking was no different significantly with each type of heel. With wedge heels, it was $1141.55\mu V$; with setback heels, it was $1215.13\mu V$; and with french heels, it was $1137.56\mu V$.

On the other hand, the muscle activation of the C6 paraspinal muscles in wearing wedge heels differed significantly according to walking velocity($p<.05$). For the setback heels, the muscle activation of the C6 paraspinal muscles differed significantly according to walking velocity($p<.05$). For the french heels, the muscle activation of the C6 paraspinal muscles differed significantly according to walking velocity($p<.05$)(Table 1). In all types of high heels, the muscle activation of the C6 paraspinal muscles induced by slow walking($p<.05$) and by fast walking($p<.05$) was higher than that induced by standing position. And

Table 1. Muscle activation of cervical paraspinal muscles in different types of high heels and in different velocity (unit: μV)

Heel Type	Standing	Slow walking	Fast walking	F	p
Wedge	187.14±95.26	815.90±498.95a	1141.55±697.35bc	43.96	.00
Setback	202.56±132.47	850.64±533.70a	1215.13±648.68bc	63.02	.00
French	201.20±132.63	933.83±555.18a	1137.56±595.10bc	55.72	.00
F	.28	1.14	.89		
P	.768	.32	.40		

a: standing<slow walking, b: standing<fast walking, c: slow walking<fast walking

The muscle activation of the C6 paraspinal muscles induced by fast walking($p<.05$) was higher than that induced by slow walking.

2. Muscle activation of thoracic paraspinal muscles in different types of high heels and in different velocity

The muscle activation of the T7 paraspinal muscles in the standing position was no different significantly with each type of heel. With wedge heels, it was $138.33\mu V$; with setback heels, it was $167.67\mu V$; and with french heels, it was $162.25\mu V$. The muscle activation of the T7 paraspinal muscles in the slow walking differed significantly with each type of heel. With wedge heels, it was $653.68\mu V$; with setback heels, it was $748.80\mu V$; and with french heels, it was $761.68\mu V$. Especially the muscle activation of the T7 paraspinal muscles induced by setback heels($p<.05$) and by french heels($p<.05$) was higher than that induced by wedge heels. The muscle activation of the T7 paraspinal muscles in the fast walking was no different significantly with each type of heel. With wedge heels, it was $986.58\mu V$; with setback heels, it was $1079.62\mu V$; and with french heels, it was $1031.60\mu V$.

On the other hand, the muscle activation of the T7 paraspinal muscles in wearing wedge heels differed significantly according to walking velocity($p<.05$). For the setback heels, the muscle activation of the T7 paraspinal muscles differed significantly according to walking velocity

($p<.05$). For the french heels, the muscle activation of the T7 paraspinal muscles differed significantly according to walking velocity($p<.05$)(Table 2). In all types of high heels, the muscle activation of the T7 paraspinal muscles induced by slow walking($p<.05$) and by fast walking($p<.05$) was higher than that induced by standing position. And The muscle activation of the T7 paraspinal muscles induced by fast walking($p<.05$) was higher than that induced by slow walking.

3. Muscle activation of lumbar paraspinal muscles in different types of high heels and in different velocity

The muscle activation of the L5 paraspinal muscles in the standing position was no different significantly with each type of heel. With wedge heels, it was $265.49\mu V$; with setback heels, it was $310.64\mu V$; and with french heels, it was $292.27\mu V$. The muscle activation of the L5 paraspinal muscles in the slow walking was no different significantly with each type of heel. With wedge heels, it was $1635.3\mu V$; with setback heels, it was $1671.92\mu V$; and with french heels, it was $1641.24\mu V$. The muscle activation of the L5 paraspinal muscles in the fast walking was no different significantly with each type of heel. With wedge heels, it was $1997.06\mu V$; with setback heels, it was $2354.93\mu V$; and with french heels, it was $2129.08\mu V$.

On the other hand, the muscle activation of the L5 paraspinal muscles in wearing wedge heels differed

Table 2. Muscle activation of thoracic paraspinal muscles in different types of high heels and in different velocity (unit: μV)

	Standing	Slow walking	Fast walking	F	p
Wedge	138.33±119.57	653.68±374.68a	986.58±560.71bc	50.05	.00
Setback	167.67±128.92	748.80±348.89a†	1079.62±518.39bc	84.22	.00
French	162.25±117.65	761.68±332.93a‡	1031.60±476.24bc	80.18	.00
F	1.08	4.41	1.23		
p	0.35	0.02	0.30		

a: standing<slow walking, b: standing<fast walking, c: slow walking<fast walking

† : wedge<setback, ‡ : wedge<french

significantly according to walking velocity($p<.05$). For the setback heels, the muscle activation of the L5 paraspinal muscles differed significantly according to walking velocity ($p<.05$). For the french heels, the muscle activation of the L5 paraspinal muscles differed significantly according to walking velocity($p<.05$)(Table 3). In all types of high heels, the muscle activation of the L5 paraspinal muscles induced by slow walking($p<.05$) and by fast walking($p<.05$) was higher than that induced by standing position. And The muscle activation of the L5 paraspinal muscles induced by fast walking($p<.05$) was higher than that induced by slow walking.

IV. Discussion

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(1997) have researched the effects of high heels on the lumbar muscles by measuring muscle fatigue while wearing high heels of(4cm, 6cm and 8cm) and while wearing shoes without heels(0cm). Their research has demonstrated that the fatigue of lumbar muscles was less serious when the high heel was 4cm high or less. However a large increase in muscle fatigue was demonstrated when the high heel was higher than 6cm.

Choi and Lee(2002b) stated that as the height of the 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(2012) performed a research on 28 females in their 20s with a foot size of 235-240mm. 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(1994)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(1988) 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(2002) 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

Table 3. Muscle activation of lumbar paraspinal muscles in different types of high heels and in different velocity (unit: μV)

	Standing	Slow walking	Fast Walking	F	P
Wedge	265.49±168.68	1635.35±1036.82a	1997.06±1165.09bc	59.04	.00
Setback	310.64±220.70	1671.92±1240.79a	2354.93±1663.57bc	33.99	.00
French	292.27±207.65	1641.24±1061.05a	2129.08±1223.85bc	64.23	.00
F	.97	.14	2.09		
P	.39	.87	.16		

a: standing<slow walking, b: standing<fast walking, c: slow walking<fast walking

heel height affects the lumbar and lower extremity muscle activity, whereas the width of the heel does not affect it. Jeong(2004) 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.

Even though that, there was no study to examine the effects of walking velocity in wearing high-heeled shoes on muscle activation of the paraspinal muscles at the cervical, the thoracic, and the lumbar. We thought there would be some relations between the walking velocity and the change of range in movement of human body central point. Hence we did a research on the effect of walking velocity on the muscle activation of paraspinal muscles. And as a result, we could see that the muscle activation in paraspinal muscles by slow walking and by fast walking was higher than it by standing. And the muscle activation in paraspinal muscles by fast walking was higher than it by the slow walking. This result matches the result of Opila et al(1988). They concluded that the side movement of human body was increased when walking on faster speed than walking slowly. However, they could not find the difference of the side movement of human body according to the different types of high heels. Hence, we can see that the paraspinal muscles are affected by the walking velocity instead of the types of high heels. Consequently, the level of tension of paraspinal muscles are more affected by the walking velocity instead of the type of the heels. But we did not examine the changes of muscle activation in walking with wearing high-heeled shoes at a slope way. So we will perform additional study about that.

V. Conclusion

This study researched the effects of different types of high heels (including wedge heel, setback heel, and french heel which are all 8cm high) on the surrounding muscles of cervical, thoracic and lumbar spine. In view of the results, the height of heels and the walking velocity are more convincing variables than the width of the heels on the muscle activation of paraspinal muscles. So wearing high heels is not recommended for those who have pain or functional problem of cervical and lumbar vertebrae.

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