

The Effects of Wearing High Heels while Pressing a Car Accelerator Pedal on Lower Extremity Muscle Activation

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Abstract. [Purpose] The purpose of this study was to determine the effects of wearing high heels while driving on lower extremity muscle activation. [Subjects] The subjects of this experimental study were 14 healthy women in their 20s who normally wear shoes with high heels. [Methods] The subjects were asked to place their shoes on an accelerator pedal with the heel touching the floor and then asked to press the pedal with as much pressure as possible for 3 seconds before removing their feet from the pedal. A total of 3 measurements were taken for each heel height (flat, 5 cm, 7 cm), and the heel height was randomly selected. [Results] The levels of muscle activity, indicated as the percentage of reference voluntary contraction, for gastrocnemius muscle in the flat, 5 cm, and 7 cm shoes were 180.8±61.8%, 285.4±122.3%, and 366.2±193.7%, respectively, and there were significant differences between groups. Those for the soleus muscle were 477.3±209.2%, 718.8±380.5%, and 882.4±509.9%, and there were significant differences between groups. [Conclusion] To summarize the results of this study, it was found that female drivers require greater lower extremity muscle activation when wearing high heels than when wearing low heels. Furthermore, instability and muscle fatigue of the ankle joint, which results from wearing high heels on a daily basis, could also occur while driving.

Key words: High heel, Muscle activation, Car accelerator pedal

(This article was submitted Mar. 4, 2014, and was accepted May 11, 2014)

INTRODUCTION

Shoes can be selected on the basis of mobility and functionality, but more emphasis has been placed in recent times on the aesthetic appeal of footwear. Many women wear high heels of various shapes and live their daily lives while wearing high heels¹⁾. A total of 59% of females wear high heels eight hours a day²⁾, and this puts many women in a position of having to make difficult choices between balancing fashion and comfort when selecting their shoes. Wearing high heels is related to a deterioration in body alignment, and it can lead to ankle instability by changing the static and dynamic body alignment characteristics. The increase in muscle activity of the plantar flexor resulting from wearing very high heels can reduce stability due to muscle imbalances of the feet and ankle joints. It can also decrease one's ability to respond to unexpected resistance by increasing muscle fatigue and decreasing the muscle control ability of the ankle joint³⁾.

Driving posture is an important element to be considered in the ergonomic design of cars. When designing and

manufacturing cars, in order to provide maximum comfort and safety, the complex biomechanical elements of the human musculoskeletal system are taken into consideration⁴⁾. Pressing of the accelerator and brake pedals, which are important elements of car control, can be restricted by the user's shoes⁵⁾. In addition, wearing high heels, while driving, can cause discomfort when operating the pedals and could also prove to be hazardous.

The majority of previous studies associated with high heels have focused on variables related to gait^{6, 7)}, whereas most of the studies on the relationship between cars and humans have considered the designs of seating positions that offer optimal comfort⁵⁾ regardless of footwear. However, when one considers the amount of time that modern women spend in cars, studies that have dealt with the effects of wearing high heels while pressing on pedals have been lacking. Therefore, the purpose of this study was to determine the effects of wearing high heels while driving on lower extremity muscle activation.

SUBJECTS AND METHODS

The subjects of this experimental study were 14 healthy women in their 20s who wear shoes with high heels more than three times a week. Their average age, weight, and height were 23.78 ± 3.22 years, 59.02 ± 7.88 kg, and 162.65±5.29 cm, respectively. None of the subjects had experienced any pathologic symptoms in the feet and legs for

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Table 1. Average muscle activation for each heel height (Unit: %RVC)

Muscle	Flat shoes	5 cm	7 cm
Rectus femoris	133.5±27.5 ^a	163.5±71.2 ^a	177.7±69.3 ^a
Tibialis anterior	160.9±104.8 ^a	205.6±86.2 ^a	213.3±74.1 ^a
Gastrocnemius*	180.83±61.7 ^a	285.39±122.2 ^a	366.15±193.7 ^b
Soleus*	477.28±209.2 ^a	718.77±380.5 ^a	882.35±509.9 ^b

Each value represents the mean±SD. The values with different superscripts in the same column are significantly different ($p<0.05$) by Tukey's test.

the last 6 months, and none had any history of operation on the lower extremities. Further, they also had no history of neurological disease. Before taking part, all of the participants were thoroughly briefed about the experimental procedures and asked to read and sign a consent form.

The subjects were then asked to select their shoe sizes, 23.0 cm, 23.5 cm, or 24.0 cm for identical high-heeled shoes of two different heights (5 cm and 7 cm) and flat shoes of sizes, which had been prepared for this experiment. In order to measure the lower extremity muscle activation occurring while pressing a pedal when wearing high heels, the subjects were asked to sit in the driver's seat of a car (Elantra HD, Hyundai Motor Company, South Korea). They were then allowed to adjust the seat-back angles and the pedal-to-seat distance so that they were able to operate the accelerator pedal with ease. The subjects, after finding comfortable driving positions, were asked to place the appropriate shoes on the accelerator pedal with the heel touching the floor and then asked to press the pedal with as much pressure as possible for 3 seconds before removing their feet from the pedal. A total of 3 measurements were taken for each heel height, and the heel height was randomly selected. In order to avoid muscle fatigue, the participants were given a short rest of 30 seconds after each measurement. Electromyographic (EMG) measurements were taken from the moment the pedal was pressed to the moment when the pedal was released.

To measure the lower extremity muscle activation, electrodes were attached to the rectus femoris, tibialis anterior, gastrocnemius, soleus were selected. Electrodes were also attached to the right leg.

ProComp Infiniti™ (Thought Technology Ltd., Montreal, QC, Canada) was employed for measurement of the muscle activation of each muscle. A surface electrode (Triode surface electrode, Thought Technology Ltd., Montreal, QC, Canada) consisting of a tripolar electrode (positive-ground-negative) was used. The frequency range of the electromyogram signals was set to 20 to 500 Hz, and the sampling frequency was set to 1,024 Hz.

The root mean square of each muscle was measured for five seconds while the subjects sat in the driver's seat. The relative muscle contraction was calculated referring to 100% of the mean electromyogram signal measured for the three seconds in the middle, excluding the data of the first one second and the last one second, and expressed as the muscle activation in terms of the percentage of reference voluntary contraction (%RVC) for one instance of pushing the accelerator.

PASW for Windows (Ver. 19) was used for data analysis. In order to determine the difference between wearing high heels and low heels, one-way analysis of variance test (ANOVA) was carried out, and Tukey's test was used as a post hoc test to verify differences. The level of significance was 0.05.

RESULTS

The levels of muscle activity for the gastrocnemius muscle in the flat, 5 cm, and 7 cm shoes were 180.83±61.78%, 285.39±122.25%, and 366.15±193.73%, respectively, and there were significant differences between groups. The post hoc test showed a significant difference between the flat and 7 cm shoes. Those for the soleus muscle were 477.28±209.21%, 718.77±380.50%, and 882.35±509.93%, respectively, and there were significant differences between groups. The post hoc test showed a significant difference between the flat and 7 cm shoes (Table 1).

DISCUSSION

While an increase in heel height affects the stability and mobility of feet greatly¹⁾, it has also been reported that the gait when high heels are worn greatly affects the stability of the ankle joint by increasing the plantar flexion of the ankle joint and readily inducing muscle fatigue⁸⁾. Most of the previous studies have looked into the gait resulting from the change in the body's center of gravity when wearing high heels and the kinetic and kinematic properties that are required to maintain balance while standing^{9, 10)}. However, in this study, the intention was to determine the effects of wearing high heels while in a sitting position, that is, when the majority of the body's center of gravity is supported by all the muscles of the trunk.

Plantar flexion and dorsiflexion of the ankle joint are the movements associated with pressing the accelerator and releasing the accelerator of a car. The results of the present study showed that with an increase in heel height, the muscle activation increased in the gastrocnemius and soleus ankle joint plantar flexion agonists, especially with a heel height of 7 cm, which resulted in a statistically significant increase in muscle activation. Despite statistically insignificant data, it was found that as the heel height increased, the tibialis anterior muscle activation of ankle joint dorsiflexion agonist have also increased. This appeared to be the result of an increased plantar flexion angle resulting from the increase in heel height: the movement of pressing the accelerator pedal results in ankle joint plantar flexion and

dorsiflexion. In addition, although not a statistically significant increase, the muscle activation of the rectus femoris tended to increase with an increase in heel height, and this was the result of an increase in knee joint extension. This concurs with the results of a previous study, which found that the proximal part required preceding contraction due to the instability of the distal part in the ankle joint with an increase in heel height¹¹.

To summarize the results of this study, it was found that female drivers require greater lower extremity muscle activation when wearing high heels than when wearing low heels. Furthermore, the instability and muscle fatigue of the ankle joint, which result from wearing high heels on a daily basis, can also occur while driving.

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