

Original Article

# Effect of Different Forefoot and Heel Support Surfaces on the Activities of the RF and HAM Muscles during the Sit-to-stand Task while Wearing High-heel Shoes

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**Abstract.** [Purpose] The purpose of this study was to show the effect of different forefoot and heel support surfaces on the activities of the rectus femoris and medial hamstring muscles during the sit-to-stand task while wearing high-heel shoes. [Subjects] Fifteen female subjects were recruited. [Methods] The muscle activities of the rectus femoris and hamstring muscles were recorded using an MP150 system during the sit-to-stand task while wearing various high-heeled shoes. [Results] The activities of the rectus femoris and medial hamstring muscles significantly decreased when subjects wore condition 1 shoes compared with when they wore condition 2, 3 or 4 high-heeled shoes. The activities of the rectus femoris and medial hamstring muscles significantly decreased when subjects wore condition 2 high-heeled shoes compared with condition 3 or 4 high-heeled shoes. [Conclusion] The results can be interpreted as indicating that the size of the forefoot supporting surface can influence the lower extremity muscles of women wearing high-heeled shoes more than the size of the heel supporting surface.

**Key words:** High-heeled shoes, Imbalance, Sit-to-stand

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## INTRODUCTION

In recent years, young women have been wearing high-heeled rather than low-heeled shoes to make themselves look taller or slimmer and more fashionable<sup>1, 2)</sup>. Young women wearing high-heeled shoes to make themselves look taller and fashionable must be aware that this can induce musculoskeletal disorders due to foot deformation and imbalance in lower extremity muscles, but these adverse effects do not appear to stop many young women from frequently wearing high-heeled shoes<sup>3)</sup>. The effects of the type and height of shoe heels on the body have been revealed to exhibit differences in terms of lower extremity mechanics and energy cost with heel height<sup>4)</sup>. However, few studies have investigated the effects of different forefoot support surfaces and heel support surfaces in high-heeled shoes. The sit-to-stand (STS) motion requires optimal neuromuscular coordination to control the moment changes and to prevent excessive energy generation or loss of balance<sup>5)</sup>. Impaired neuromuscular patterns may induce neuromuscular disorders and abnormal postural adjustments<sup>6)</sup>. The purpose of this study was to show the effects of various

forefoot support surfaces and heel support surfaces in high-heeled shoes on the activations of the rectus femoris (RF) and medial hamstring (HAM) muscles during the STS task.

## SUBJECTS AND METHODS

The subjects of this study were 15 females in their twenties who wore high-heeled shoes for more than six hours daily (age, 20.8±0.8 years [mean±SD]; height, 159.8±2.7 cm; weight, 50.4±4.6 kg; duration of wearing high-heeled shoes, 5.0±1.7 hours/day). None of the subjects had a history of ankle joint injury, foot deformities, or dysfunction of the neuromuscular or musculoskeletal system. Each subject provided informed consent before participating in the study. This study was approved by the Yonsei University Faculty of Health Sciences Human Ethics Committee. The muscle activities of the RF and HAM muscles were recorded using a MP150 system. All of the EMG signals were sampled at 1,000 Hz, and then analyzed using the Acqknowledge 3.9.1 software (Biopac Systems, Santa Barbara, CA, USA). The root mean square values of the raw data were calculated, with the amplitude normalized to the maximum voluntary isometric contraction. We selected shoes with 7-cm high heels of various sizes from 230 to 250 mm, all of which were made from the same material of S company in order to avoid material-related effects. The 4 high-heel shoe conditions were as follow: condition 1 shoes had a forefoot support surface of 56±5 cm<sup>2</sup> and heel support surface of 4±1.0 cm<sup>2</sup>, condition 2 shoes had a forefoot support surface

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**Table 1.** Comparisons of the RF and HAM muscles under the 4 conditions

Muscles	Conditions (% , mean $\pm$ SD)			
	1	2	3	4
RF	41.0 $\pm$ 5.9	45.8 $\pm$ 7.0	55.2 $\pm$ 7.4	56.6 $\pm$ 9.2
HAM	10.0 $\pm$ 3.8	15.7 $\pm$ 5.2	19.9 $\pm$ 8.1	22.0 $\pm$ 6.0

of 56 $\pm$ 5 cm<sup>2</sup> and heel support surface of 1 $\pm$ 0.2 cm<sup>2</sup>, condition 3 shoes had a forefoot support surface of 42 $\pm$ 3 cm<sup>2</sup> and heel support surface of 4 $\pm$ 1.0 cm<sup>2</sup>, condition 4 shoes had a forefoot support surface of 42 $\pm$ 3 cm<sup>2</sup> and heel support surface of 1 $\pm$ 0.2 cm<sup>2</sup>. The contact surface of the high heel was measured using a CONFORMat System (Model #5330, Tekscan, Boston, MA, USA). This system is a portable interface pressure mapping system. They were asked to perform three repetitions of an STS task under three heel-height conditions. Subjects sat in a relaxed and comfortable position with their back straight and arms folded, and they were instructed to not perform intentional muscle contractions and to maintain a relaxed and comfortable seating position. Subjects were asked to rise from the chair when instructed verbally by the word “go”. The STS task was performed at a self-selected velocity. Subjects were asked to maintain the standing posture for more than 5 s after completing the STS task. The SPSS statistical package (SPSS, Chicago, IL, USA) was used to analyze differences in the RF and HAM muscle activities. The significance of differences between the 4 high-heel shoe conditions was tested using one-way repeated measures ANOVA, and significance was accepted for values of  $p < 0.05$ .

## RESULTS

The activities of the RF and HAM muscles significantly decreased when subjects wore condition 1 shoes compared with condition 2, 3, or 4 shoes ( $p < 0.05$ ). Also, the activities of the RF and HAM muscles significantly decreased when subjects wore condition 2 shoes compared with condition 3 or 4 shoes ( $p < 0.05$ ). There was no significant difference between condition 3 and 4 shoes ( $p > 0.05$ ) (Table 1).

## DISCUSSION

The purpose of this study was to show the effects of various forefoot support surfaces and heel support surfaces in high-heeled shoes on the activations of the RF and HAM muscles during the STS task. According to the present study results, the muscle activities of the RF and HAM muscles were the lowest under the condition of wide supporting surfaces at the forefoot and heel of the high-heeled footwear. Generally, although a heel height has been regarded as one of the reasons for the increase in tension in the muscles of lower limbs<sup>2, 7)</sup>, it has also been proposed that a narrower sole supporting surface due to the characteristics of high-

heeled footwear should be included newly as a reason for the increase in tension in muscles of the lower limbs, as it increases the instability of the lower limbs. High-heeled footwear that can increase muscle activity in the RF may increase anterior shear force of the knees thereby inducing knee pain easily<sup>7, 8)</sup>. In addition, high-heeled footwear that can increase muscle activity in the HAM could limit pelvic movement during trunk flexion and induce excessive flexion in the lumbar region thereby causing back pain<sup>7, 8)</sup>. According to the results of the present study, the conditions 1 and 2 shoes, which had wider forefoot supporting surfaces, resulted in less tension in the RF and HAM muscles compared with the conditions 3 and 4 shoes, which had smaller supporting surfaces. Furthermore, no significant difference was found in comparison of the heel supporting surfaces between the conditions 3 and 4 shoes. This result can be interpreted as indicating that the size of the forefoot supporting surface can influence the lower extremity muscles of women wearing high-heeled shoes more than the size of the heel supporting surface. In general, the design of high heels is focused on the heel, and most women are interested in the heel's design<sup>2, 3)</sup>. According to the present study, an optimized design can be developed by maintaining the aesthetic aspects of high-heeled footwear through design improvements that widen the forefoot supporting surface regardless of heel's design while resolving the negative aspects of high-heeled footwear.

## REFERENCES

- 1) Edwards L, Dixon J, Kent JR, et al.: Effect of shoe heel height on vastus medialis and vastus lateralis electromyographic activity during sit to stand. *J Orthop Surg*, 2008, 3: 2. [[Medline](#)] [[CrossRef](#)]
- 2) Esenyel M, Walsh K, Walden JG, et al.: Kinetics of high-heeled gait. *J Am Podiatr Med Assoc*, 2003, 93: 27–32. [[Medline](#)] [[CrossRef](#)]
- 3) Franklin ME, Chenier TC, Brauninger L, et al.: Effect of positive heel inclination on posture. *J Orthop Sports Phys Ther*, 1995, 21: 94–99. [[Medline](#)] [[CrossRef](#)]
- 4) Yoon JY, An DH, Yoo WG, et al.: Differences in activities of the lower extremity muscles with and without heel contact during stair ascent by young women wearing high-heeled shoes. *J Orthop Sci*, 2009, 14: 418–422. [[Medline](#)] [[CrossRef](#)]
- 5) Papa E, Cappozzo A: Sit-to-stand motor strategies investigated in able-bodied young and elderly subjects. *J Biomech*, 2000, 33: 1113–1122. [[Medline](#)] [[CrossRef](#)]
- 6) Hodges PW: Changes in motor planning of feedforward postural responses of the trunk muscles in low back pain. *Exp Brain Res*, 2001, 141: 261–266. [[Medline](#)] [[CrossRef](#)]
- 7) Neumann DA: *Kinesiology of the musculoskeletal system: foundations for physical rehabilitation*. St Louis: Mosby, 2009.
- 8) Sahrman SA: *Diagnosis and treatment of movement impairment syndromes*. St. Louis: Mosby, 2002.