



Original Article

## Effect of rain boot shaft length on lower extremity muscle activity during treadmill walking

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**Abstract.** [Purpose] This study aimed to determine the extent of lower extremity muscle activity before and after walking based on rain boot shaft length. [Subjects and Methods] The subjects, 12 young and healthy females, were divided into three groups based on rain boot shaft length (long, middle, and short). They walked on a treadmill for 30 minutes. Activity of the rectus femoris, vastus lateralis, semitendinosus, tibialis anterior, peroneus longus, and gastrocnemius was measured using electromyography before and after walking. Two-way repeated measures analysis of variance was performed to compare the muscle activities of each group. [Results] There were no significant differences in terms of the interactive effects between group and time for all muscles, the main effects of group, or the main effects of time. [Conclusion] The results of this study may indicate that movement of the lower extremities was not significantly limited by friction force based on the characteristics of the boot material or the circumference of the boot shaft. Thus, it may be helpful instead to consider the material of the sole or the weight of the boots when choosing which rain boots to wear.

**Key words:** Electromyography, Rain boot, Treadmill walking

*(This article was submitted Mar. 29, 2016, and was accepted May 23, 2016)*

### INTRODUCTION

The important functions of shoes include protecting the feet and enabling movement without pain. Shoes influence the stability of posture by accepting feedback from the somatosensory system including changes in friction between the shoes and the soles of the feet<sup>1)</sup>. Generally speaking, shoes are used as a means of basic transport for human beings during such activities as walking and jogging, and as a means of enhancing physical strength<sup>2)</sup>. Hemp, straw, wood, and leather have mainly been used as material for shoes in the past, while various other materials, including rubber, cloth, and plastic, are more frequently used today. The types of shoes currently available are quite diverse and subdivided, including high heels for beauty, slippers for comfort, running shoes for exercise, military boots for physical hardship, and aqua shoes for water activities<sup>3)</sup>.

Electromyography (EMG) records information on bioelectrical activities related to muscle contraction and muscle control, and can illustrate the relationships between anatomical movements and temporal aspects of the human body, energy generation and EMG, and muscle fatigue and EMG<sup>4)</sup>.

A previous study on shoes related to falling in the elderly reported that heel height, sole hardness, and tread and heel geometry affected both, balance and walking<sup>5)</sup>. Another study focusing on basketball players reported no relationship between shoe design and ankle sprain<sup>6)</sup>. Furthermore, a previous study investigating the effect of high-top versus low-top shoes on ankle inversion kinematics and prelanding EMG activation of the ankle evertor muscles during landing on a tilted surface

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demonstrated that wearing high-top shoes can induce delayed preactivation timing and decreased evetor muscle activity<sup>7)</sup>.

Recently, although the aesthetic interest in shoes and the types of shoes that are worn have varied, most previous studies have focused on muscle activity based on shoe type, such as high heels and sneakers. In this study, the rain boots, which have recently become a representative fashion item for females, and the effect of boot shaft length on lower extremity muscle activity while walking were investigated.

## SUBJECTS AND METHODS

Among female students aged in their twenties who were attending a college located in Cheonan City, South Korea, 12 healthy females who had not experienced surgical impairment within the past year and who did not feel pain while walking were selected for inclusion in this study (Table 1). They understood the purpose and content of this experiment, and voluntarily provided informed consent before the experiment. This study was approved by the Institutional Review Board of Namseoul University (No. NSU-141006-1).

Three types of rain boots, based on shaft length, were investigated; heel height was standardized as 3.5 cm (Table 2). A body composition analyzer (Inbody 720; Biospace O. Ltd., Seoul, Republic of Korea) was used to measure the physical characteristics of the subjects. While the subjects walked on a treadmill (SNS Care m-400m; SNS Care Co., Ltd., Goyang-si, Republic of Korea) while wearing rain boots, a wireless surface EMG system (Free EMG; BTS Inc., Milan, Italy) was used to measure lower extremity muscle activity and muscle fatigue.

In this single-sample repeated measures experiment, the subjects were divided into three groups based on rain boot shaft length: long, middle, and short. Electrodes were attached to the subjects to measure muscle activity before the experiment and immediately after walking on a treadmill at 3.6 km/h constantly<sup>8)</sup> for 30 minutes<sup>9)</sup> while wearing rain boots.

For measurement of muscle activity, 4 × 3.5 cm surface electrodes (3 M Red Dot 2570; 3 M Center, St. Paul, MN, USA) were used. The surfaces were shaved and washed with medical alcohol to attach the electrodes<sup>10)</sup>. The electrodes were attached to the rectus femoris (RF), vastus lateralis (VL), semitendinosus (ST), tibialis anterior (TA), peroneus longus (PL), and gastrocnemius (GM, medial part). For the RF, electrodes were attached to the halfway point between the patella anterior to the femur and the anterior iliac spine<sup>11)</sup>; for the VL, the point 50° relative to the femoral longitudinal axis and over 5 cm from the superomedial patella toward the vastus medialis<sup>12)</sup>; for the ST, the middle point between the ischial tuberosity and the tibia, and 3 cm to the inside of the ST<sup>11)</sup>; for the TA, the point 33% from the tip of the fibula toward the medial malleolus; for the PL, the point 25% from the fibular head toward the lateral malleolus<sup>13)</sup>; and for the GM, the point 35% inside and 2 cm over the distal midline of the knee joint. For all cases, the distance between the electrodes was 2 cm<sup>11)</sup>. All of the electrodes were attached by the same researchers. In order to avoid errors that might affect the experiment, the electrodes were attached at the state of maximal static contraction.

SPSS version 18.0 for Windows (IBM Corporation, Armonk, NY, USA) was used for statistical analysis. The general characteristics of the subjects were expressed as means and standard deviations. The Kolmogorov-Smirnov test was used to prove normality, and Levene's F test was used to assess the homogeneity of the subjects. Two-way repeated measures analysis of variance was performed to compare the muscle activities of each group before and after walking. Scheffé's test was used for post hoc analysis in case of a significant difference. The level of statistical significance was set at  $\alpha=0.05$ .

## RESULTS

When muscle activities based on boot shaft length were compared, there were no significant differences in terms of the interaction between group and time among the six muscles measured in this study. In addition, no significant differences were found in the main effects of group or time (Table 3).

## DISCUSSION

Shoes are important for protecting the human body, and those worn during exercise are useful for preventing injury in several joints, including the ankle, by absorbing the impact of landing while walking and running<sup>2)</sup>. Shoes have been developed to serve different purposes, and the types of shoes that are worn vary based on an individual's particular interests. In this context, this study investigated lower extremity muscle activity based on rain boot shaft length, since these boots have become a popular fashion item among young females.

**Table 1.** General characteristics of the subjects

Characteristic	Mean ± SD
Age (yrs)	20.5 ± 0.5
Height (cm)	159.0 ± 4.9
Weight (kg)	51.4 ± 7.2

**Table 2.** General characteristics of the rain boots

Boots	Length (cm)	Weight (kg)
Long	40.0	1.6
Middle	29.0	1.3
Short	17.0	0.8

When muscle activities based on boot shaft length were compared in this study, there were no significant differences in the interaction between group and time among the six muscles. In addition, no significant differences were found in the main effects of group or time.

A previous study investigating the effect of high-top versus low-top sneakers on ankle inversion reported that the former were more effective in reducing ankle inversion and might be slightly more helpful in preventing ankle sprain based on loading conditions<sup>14</sup>). Another study exploring the effect of shoes on Achilles tendon loading reported that high-top sneakers were more effective in reducing peak Achilles tendon tension<sup>15</sup>). The effects of shoe collar height on the kinematics and kinetics of the ankle joint in athletic performance during unanticipated maximum-effort side-cutting also have been explored. It was reported that high-collar shoes reduced ankle inversion and external rotation of the planting leg during initial contact, and showed less ankle joint range in the sagittal and transverse planes. However, ankle movement and performance indicators, including cutting performance time, ground contact time, and propulsion ground reaction forces and impulses, were not affected by collar height. Such results indicate that high-collar shoes do not have a negative effect on athletic cutting performance, but, instead, transform ankle positioning and restrict ankle joint freedom<sup>16</sup>).

Contrary to previous studies, no significant differences were found in muscle activities in this study, indicating that rain boot shaft length did not play a critical role in restricting lower extremity movement. Unlike the characteristics of the material used in sneakers, rain boots did not restrict joint range, owing to the flexibility of the soles, despite the long shaft. They also did not affect muscle activity based on shaft length because of the characteristics of the rubber and the large circumference of the shaft.

This study has several limitations. First, the results would be difficult to generalize because muscle activity was analyzed in a small number of samples. Second, all of the subjects were young, healthy females. Third, this study analyzed EMG only. Therefore, further studies involving a larger number of samples including various types of subjects, such as athletes, elderly individuals, and specific patients, are required. In addition, relative analysis has to be performed for various variables regarding the rain boots, such as joint angle and proprioception.

In conclusion, the lower extremity muscle activity based on rain boot shaft length was investigated because these boots are commonly used in the rainy season for practical reasons and have become a fashion item for young females, resulting in no significant differences among the activities of all six muscles measured in this study. The results of this study may suggest that movement of the lower extremities was not restricted by friction force based on the characteristics of the boot material (rubber) or the circumference of the boot shaft. Thus, it may be helpful instead to consider the material of the sole or the weight of the boots when choosing rain boots for practical purposes.

**Table 3.** Pre- and post test muscle electromyographic results according to rain boot group (mV)

Variable	Group	Pretest		Posttest	
		Mean	± SD	Mean	± SD
RF	Long	32.0	± 17.9	55.1	± 16.7
	Middle	14.1	± 16.2	9.0	± 8.9
	Short	11.2	± 16.9	4.1	± 10.7
VL	Long	48.9	± 50.0	21.7	± 32.5
	Middle	65.4	± 54.1	57.7	± 30.3
	Short	89.3	± 50.8	153.3	± 40.6
ST	Long	184.5	± 214.6	120.0	± 151.1
	Middle	221.6	± 230.2	149.4	± 167.2
	Short	199.9	± 199.4	143.2	± 151.7
TA	Long	45.2	± 41.8	15.1	± 17.3
	Middle	42.7	± 40.7	23.4	± 19.8
	Short	38.4	± 37.2	18.9	± 15.8
PL	Long	46.5	± 42.6	10.5	± 18.0
	Middle	36.2	± 18.3	38.4	± 17.7
	Short	36.1	± 15.2	36.5	± 17.6
GM	Long	52.7	± 26.8	49.8	± 14.8
	Middle	43.3	± 23.1	45.0	± 22.4
	Short	52.4	± 29.3	48.8	± 27.2

GM: gastrocnemius; PL: peroneus longus; RF: rectus femoris; ST: semitendinosus; TA: tibialis anterior; VL: vastus lateralis

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