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Original Article

# EMG Activity of the Abductor Hallucis Muscle during Foot Arch Exercises Using Different Weight Bearing Postures

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**Abstract.** [Purpose] This study examined the effects of different weight-bearing postures on the activation of the abductor hallucis muscle during foot-arch exercises. [Subjects] The study recruited 11 healthy volunteers who were pain-free, had no history of foot or ankle surgery, and were able to maintain a standing posture. [Methods] The subjects performed short-foot and toe-spreading exercises while sitting and standing. [Results] The abductor hallucis muscle activation in the toe-spreading exercise was significantly greater when standing than in sitting, while that in the short-foot exercise did not differ significantly between the two postures. [Conclusion] The results of this study suggests that a weight bearing posture such as standing is the most effective method of increasing the EMG activity of abductor hallucis muscle in the toe-spreading exercise.

**Key words:** Short foot exercise, Toe spreading exercise, Weight bearing

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## INTRODUCTION

Weight-bearing exercises are often beneficial for strengthening muscles and they are being increasingly used in clinical practice. Typically, weight-bearing exercises in a standing posture are performed while the feet are in contact with a stable floor or an object that generates compressive forces at the hip, knee, and ankle joints resulting from an individual's body weight. Weight-bearing exercises increase muscle strength and neuromuscular control of the lower extremities in young athletes[1, 2)]. Partial weight-bearing exercises are used for patients with painful knee osteoarthritis or inflammation in the hip or knee joints[3, 4)].

Foot-arch exercises are used to reinforce the arch of the foot and strengthen the plantar muscles. Use of the short-foot and toe-spreading exercises has increased. These exercises increase the angle of the medial longitudinal arch[5)] and reduce the center of pressure[6)]. Heo et al.[7)] reported that short-foot and toe-spreading exercises are effective methods for selectively strengthening the abductor hallucis muscle. Kim et al.[8)] recommended the toe-spreading exercise to prevent or correct hallux valgus. The abductor hallucis muscle is an intrinsic muscle of the plantar foot, and its activity can be detected using surface electromyography (EMG)[9)].

Myers[10)] noted that the plantar fascia and short toe flexors are connected with the triceps surae muscle group on the superficial back line. The triceps surae and hamstrings are both separate and connected. Dissections show that the fascia clearly links the distal ends of the hamstrings to the proximal ends of the hamstrings and the gastrocnemii heads. According to the theory of Anatomy Trains, fascia in the lower extremity is clearly linked when the knees are extended, which leads to correct action of muscles in the lower extremity. However, almost all exercises used for strengthening the foot arch are usually performed when the subject is seated[5, 7)].

Therefore, this study investigated the effects of weight-bearing exercises performed while standing. Considering the role of fascia in muscle function[10)], we hypothesized that during foot-arch exercises the activity of the abductor hallucis muscle while weight-bearing in a standing posture would be higher than the activity with partial weight-bearing in a sitting posture.

## SUBJECTS AND METHODS

Eleven healthy volunteers (five males, six females; mean ± SD age 26.09 ± 2.91 years, height 166.54 ± 11.54 cm, mass 58.45 ± 14.13 kg) participated in this study, which was approved by the Inje University Faculty of Health Science Human Ethics Committee. All subjects gave the informed consent before participating in this study. The subjects reported no symptoms of injury at the time of testing, they were able to perform the exercises without pain, and they had no history of surgery or amputation of the foot or ankle

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in the past 6 months. The study participants' results were within the normal range (5–9 mm) in the navicular drop test[11]. The EMG signals of the abductor hallucis muscle activity was recorded using a MP150WSW data acquisition system (BIOPAC Systems, Santa Barbara, CA, USA). All of the signals were amplified, band-pass filtered (20–500 Hz), and sampled at 1,000 Hz using AcqKnowledge ver. 3.9.1, then normalized to the peak maximal voluntary isometric contraction (Peak %MVIC). The subjects practiced the short-foot and toe-spreading exercises in both the sitting and standing positions. While sitting, the trunk was maintained in an upright position during the exercise and the hips were not bent forward. In the standing posture, the feet were splayed outwards and the load of the body weight was placed on the dominant leg.

When performing the short-foot exercise, the metatarsal was drawn toward the heel without toe flexion. For the toe-spreading exercise, the toes were spread and the heel was raised. Then, the heel was lowered to the ground, increasing the medial longitudinal arch, and held in that position. The participants performed both exercises while both standing and sitting and maintained each position for 5 s. Statistical analysis was performed using SPSS ver. 17.0 (SPSS, Chicago IL, USA). The paired t-test was used to determine the significance of differences in the activity of the abductor hallucis during the short-foot exercises. Significance was accepted for values of $p<0.05$.

## RESULTS

For the toe-spreading exercise, the activation of the abductor hallucis was significantly greater ($p<0.05$) when standing than sitting (59.19±14.19 vs. 47.88±17.95%MVIC, respectively), while there was no significant difference in the results of the short-foot exercise between standing and sitting (56.43±14.97 vs. 48.98±14.95%MVIC, respectively).

## DISCUSSION

To determine the effect of weight-bearing foot-arch exercises, this study compared the short-foot and toe-spreading exercises while subjects were standing and sitting. We hypothesized that the weight-bearing exercises conducted while standing would generate greater activation than partial weight-bearing exercises while sitting for both the short-foot and toe-spreading exercises. However, no significant difference was found for the short-foot exercise. A possible reason for the differences between these two exercises is that the short-foot exercise shortens the abductor hallucis between the metatarsophalangeal joint and calcaneus, while the toe-spreading exercise maintains the stretch tension through maximal abduction of the toes. According to the length-force relationship, there is an optimal muscle length that generates the greatest muscle force, while a shortened or stretched muscle generates a lower force[12, 13]. Therefore, we believe that shortening of the abductor hallucis influenced its activity during the short-foot exercise, as evidenced by the lack of significant change in EMG activity between standing and sitting.

Our study had several limitations. First, measurements with surface EMG electrodes are always affected by cross-talk from adjacent muscles. Second, these results cannot be generalized because the sample size was small. Third, we did not quantify the amount of partial weight-bearing, so the subjects might have performed the exercises under different loads. Many studies have reported that weight-bearing exercises are more effective for strengthening the skeletal muscles. However, our results suggest that the length-force relationship should be considered for weight-bearing foot-arch exercises.

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