J.Phys. Ther. Sci
**23:** 915-918, 2011

# Comparison of Selective Activation of the Abductor Hallucis during Various Exercises

Hyo-Jin Heo[1)], Young-Mi Koo[1)], Won-Gyu Yoo[2)]

[1)] *Department of Physical Therapy, The Graduate School, Inje University*
[2)] *Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University: 607 Obangdong, Gimhae, Gyeongsangnam-do, 621-749 Republic of Korea.*
*TEL: +82 55-320-3994, FAX: +82 55-329-1678, E-mail: won7y@inje.ac.kr*

**Abstract.** [Purpose] Several exercises aim to strengthen the abductor hallucis (AbdH) of the foot arch which acts as a shock absorber. The purpose of the present study was to compare various exercises designed to strengthen the medial longitudinal arch (MLA) by selectively recruiting the AbdH in order to identify the most effective exercise method. [Subjects] Six males and six females participated in this study. [Methods] We selected and compared 5 exercises, which are known to be effective exercises. [Result] The exercise giving the highest EMG activation was EX 2 (64.43% MVIC). The second highest activation was found in EX 4 (40.50% MVIC). EMG values in EX 1 (40.12% MVIC), EX 4 and EX 5 (34.34% MVIC) were higher than in EX 3 (18.59% MVIC). EX 3 gave the lowest EMG activation of the 5 exercises. [Conclusion] The MLA plays an important role in gait and energy efficiency. Therefore, new exercises should be designed and existing exercises should be extended to incorporate new movements.

**Key words:** Medial longitudinal arch, Abductor hallucis, Electromyography

*(This article was submitted Jun. 10, 2011, and was accepted Jul. 27, 2011)*

## INTRODUCTION

The foot arch works as a shock absorber and can influence gait efficiency[1)] as well as the biomechanics of other joints such as the patellofemoral joint[2)] and spine[3,4)]. The medial longitudinal arch (MLA) is a typical example. It is supported by the shape of the foot bones, the long and short plantar ligaments, the plantar aponeurosis, and the plantar muscles and tendons[5)]. Plantar muscles are classified as extrinsic and intrinsic muscles. Extrinsic foot muscles assist in stabilizing the midtarsal joint and provide dynamic support to the MLA during the stance phase. The intrinsic foot muscles contribute to foot arch stability during propulsion[6,7)], and they include the abductor hallucis, flexor digitorum brevis and interosseous[8)]. The abductor hallucis (AbdH) is the first layer of the intrinsic muscle at the plantar surface of the foot. The proximal attachment originates at the medial process of the calcaneus tuberosity, and insertion is at the proximal phalanges, with or without attachment to the medial sesamoid bone, or with insertion exclusively at the medial sesamoid bone[9)]. The primary action of the AbdH is abduction of the metatarsophalangeal (MP) joint of the great toe, and it assists flexion of the MP joint and adduction of the forefoot[10)]. Previous studies have reported that the AbdH is critical for support of the MLA and control of pronation of the foot during static standing[11,12)]. Jung et al. (2001) described a decrease in the MLA angle with an increase in AbdH activity; therefore, AbdH exercise maintains and improves the MLA[13)].

Several exercises aim to strengthen the intrinsic muscles, including the AbdH: for example, toe curls, picking up objects, shin curls, unilateral balance activities, short foot exercises[14,15)] and toe spread exercises[16)]. The toe spread exercise is started by bringing up the heel in the sitting position. The heel is then lifted and brought a little to the inside, then put down again, while keeping the toes spread on the floor at all times[16)]. The short foot exercise activates the intrinsic muscles by shortening the foot in the anterior-posterior direction: the forefoot and heel touch the floor without toe flexion[15)]. These exercises induce a stable gait by strengthening the AbdH and controlling excessive pronation[11,12,17)].

The purpose of the present study was to compare various exercises designed to strengthen MLA by selective recruitment of AbdH to identify the most effective exercise method.

## SUBJECTS AND METHODS

*Subjects*

Twelve people (6 males and 6 females, mean age 28.4 ± 2.3 years, mean height 168.7 ± 8.1 cm, mean mass 61.3 ± 9.8 kg, mean navicular drop (ND) 5.9 ± 1.0 mm)

**Table 1.** The %MVIC of the AbdH in each exercise (n=12)

| | EX 1 | EX 2 | EX 3 | EX 4 | EX 5 |
|---|---|---|---|---|---|
| %MVIC (Mean ± SD) | 40.1 ± 12.9 | 64.4 ± 11.1 | 18.6 ± 11.9 | 40.5 ± 16.4 | 34.3 ± 12.4 |

participated in this study. No participant had any past or current inflammatory arthritis, operations to the foot or the ankle, diabetes, amputation of a lower limb, hallux valgus, hammer toe, or claw toe deformity. All participants performed the navicular drop test in order to determine the neutral foot alignment range (5~9 mm). The ND was measured with the modified Brody (1982) method during weight bearing[18]. The clinician touched the lateral and medial talar dome with his thumb and index finger, and the subject slowly moved to generate inversion and eversion. When the subtalar joint had assumed the neutral position, the clinician measured the distance between the navicular tubercle and the floor in millimeters.

*Instrumentation*

We used a MP150WSW the electromyography system (Biopac Systems, Santa Barbara, CA, USA) with EL503 surface electrodes. The EMG data were recorded using Acqknowledge 3.9.1 software (Biopac Systems) at a sampling rate of 1000 Hz. The raw signal was filtered using a bandpass digital filter between 20 and 500 Hz. In order to remove the noise caused by direct contact, the clinician used an insulator during measurements.

*Procedures*

Skin resistance was reduced by removing the keratin carefully with sandpaper and disinfecting the skin with alcohol. The AbdH activation values were measured with the active electrode attached approximately 1–2cm posterior to the navicular tuberocity. The ground electrode was attached to the lateral malleolus[19]. Measurements were made 3 times and the averages were calculated and expressed as percentages of maximal voluntary isometric contraction[20,21]. This was the maximum isometric contraction of each exercise, because the EMG measurements during the same interval were averaged. We selected 5 exercises, known as effective exercises and compared them. EX 1: Flexion of the metatarsophalangeal joint. Subjects maintained a long sitting position with the foot held at the metatarsophalangeal joint and the ankle remaining neutral. Pressure was applied to the proximal phalanx in the direction of extension[10]. EX 2: Abduction of the great toe. Subjects maintained a long sitting position. The heel was held, and pressure was exerted on the 1st metatarsal and proximal phalanx of the medial axis to create abduction of the 1st toe[10]. EX 3: Forefoot adduction. Subjects maintained a long sitting position. The heel was held, and pressure was applied to the 1st metatarsal and the proximal interphalangeal joint in the direction around the inner pressure[10]. EX 4: Toe spread exercise. Subjects sat in a chair with the hip and knee at 90 ° flexion. The toes were spread and the heel raised. Then, the heel was lowered to the ground increasing the medial longitudinal arch and held there for five seconds[16]. EX 5: Short foot exercise. Subjects assumed hip and knee flexion of 90° while sitting in a chair. The metatarsal was drawn toward the heel without toe flexion. This position was maintained for five seconds[13,14]. During all tests, the clinician's resistance against the isometric maximum force was measured for 5 seconds in each posture.

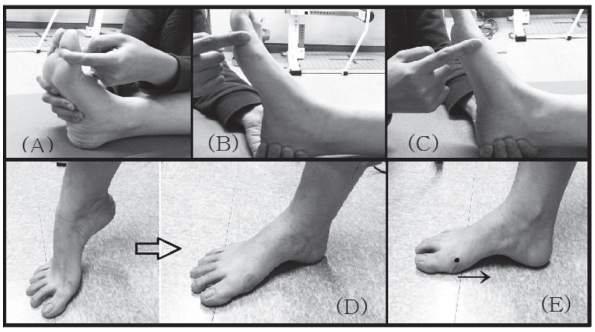


**Fig. 1.** (A) EX 1: Flexion of the metatarsophalangeal joint. (B) EX 2: Abduction of the great toe. (C) EX 3: Forefoot adduction. (D) EX 4: Toe spread exercise. (E) EX 5: Short foot exercise.

*Data analysis and statistics*

The average values of EMG activity in each AbdH exercise were compared with a one-factor repeated measured ANOVA. Statistical analysis was performed using SPSS version 17.0 (SPSS Inc., Chicago) for Windows. The post hoc Bonferroni correction was applied. Values of $p<0.05$ were considered significant.

## RESULTS

The EMG activities in the AbdH selective exercises are presented in Figure 1. The highest EMG activity in all five exercises was found in EX 2, 64% MVIC. The second highest activity was found in EX 4, 40% MVIC. The EMG activities of EX 1 (40% MVIC) and EX 5 (34% MVIC) were higher than that of EX 3 (18% MVIC). The EX 3 had the lowest EMG activity of the 5 exercises (Table 1).

## DISCUSSION

Maintenance or strengthening of the medial longitudinal arch is critical for dynamic stabilization and maintenance of energy efficiency during gait[1,6,7]. Previous studies have suggested various methods for reinforcing foot pronation caused by MLA weakness, including insoles, arch supports and taping to provide artificial protection. Mulford et al. (2008) reported that arch support improved balance and reduced pain in elderly people[22]. Finestone et al. (2004)

also indicated that use of orthotic insoles can treat pathological conditions such as overuse injury[23]. Mattila et al. (2010) mentioned that use of orthotic insoles did not prevent lower limb discomfort related to physical stress in young men; thus, he does not recommend orthotic insoles[24]. Brown et al. (1995) found no significant differences in maximum pronation, calcaneal eversion or total pronation of the foot following use of various types of arch supports[25]. Studies have also investigated the use of taping. Franettovich et al. (2008) found that application of low-dye taping to an excessively pronated foot increased the height of the MLA and decreased leg muscle activity. However, it was unclear how the tape-induced increase in the medial longitudinal arch was related to the changes in EMG activity[26].

Based on these studies, our study focused on the selective strengthening of the AbdH as an important muscle for the MLA, rather than using external treatments. We compared five exercises using 12 healthy persons. As suggested by Kendall et al. (2005), abduction of the great toe (EX 2)[10] resulted in the highest activation, 64% MVIC; the next highest activation was in the toe spread exercise (EX 4)[16] as suggested by Christa (2007). The activation of the AbdH in EX 3, which assists abduction of the hallucis was the lowest, 18% MVIC. These results are similar to those reported by Kendall et al. (2005), who showed that forefoot abduction assisted the abduction of the hallucis, but did not result in real activation of the AbdH[10]. Jung et al. (2011) compared AbdH activities between the short foot exercise and the toe curl exercise in twenty healthy subjects. The short foot exercise induced higher EMG activation than the toe curl exercise[13].

In our present study, we also compared AbdH activities between the short foot exercise and the toe spread exercise, and found no significant differences between these exercises; however, the toe spread exercise activated the AbdH to a greater extent than the short foot exercise. Therefore, the toe spread exercise as well as the short foot exercise, seem to be appropriate exercises for strengthening the arch.

This study had several limitations. First, in each of the measurements in this experiment, subjects were measured at the maximum resistance that could produce the maximum power, which is not an accurate criterion[27]. In addition, separation of the subjects with the navicular drop test criteria applied to the neutral foot cannot be generalized due to the few subjects used. Finally, the foot AbdH exists on the surface and because it is a small muscle, the EMG signal may be generated in the intrinsic muscles and other extrinsic muscles and this may cause cross-talk. The MLA as well as the AbdH are supported by several muscles. The AbdH method of measurements used in this study cannot be used for all of the intrinsic muscles of the foot.

The MLA plays an important role in gait and energy efficiency. However, more study is needed on maintaining the MLA and on strengthening exercises. Therefore, new exercises should be designed and existing exercises should be extended to incorporate new movements. The findings for the MLA in this study are presently being applied to the study of other muscles.

## ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 2011-0005580).

## REFERENCES

1) Lees A, Lake M, Klenerman L: Shock absorption during forefoot running and its relationship to medial longitudinal arch height. Foot Ankle Int, 2005, 26: 1081–1088.
2) Dierks TA, Manal KT, Hamill J, et al.: Proximal and distal influences on hip and knee kinematics in runners with patellafemoral pain during a prolonged run. J Orthop Sports Phys Ther, 2008, 38: 448–456.
3) Carpintero P, Entrenas R, Gonzalez I, et al.: The relationship between pes cavus and idiopathic scoliosis. Spine, 1994, 19: 1260–1263.
4) Queen RM, Mall NA, Hardaker WM, et al.: Describing the medial longitudinal arch using footprint indices and a clinical grading system. Foot Ankle Int, 2007, 28: 456–462.
5) Nachbauer W, Nigg BM: Effects of arch height of the foot on ground reaction forces in running. Med Sci Sports Exerc, 1992, 24: 1264–1269.
6) O'Connor KM, Hamill J: The role of selected extrinsic foot muscles during running. Clin Biomech, 2004, 19: 71–77.
7) Van Boerum DH, Sangeorzan BJ: Biomechanics and pathophysiology of flat foot. Foot Ankle Clin, 2003, 8: 419–430.
8) Mann R, Inman VT: Phasic activity of intrinsic muscles of the foot. J Bone Joint Surg Am, 1964, 46: 469–481.
9) Drake RL, Vogl W, Mitchell AW, et al.: Gray's anatomy for students. Churchill livingstone, 2009.
10) Kendall FP, McCreary EK, Provance PG, et al.: Muscles: Testing and function with posture and pain. Lippincott Williams & Wilkins, 2005, pp 400–401.
11) Fiolkowski P, Brunt K, Bishop M, et al.: Intrinsic pedal musculature support of the medial longitudinal arch: an electromyography study. J Foot Ankle Surg, 2003, 42: 327–333.
12) Headlee DL, Leonard JL, Hart JM, et al.: Fatigue of the plantar intrinsic foot muscles increases navicular drop. J Electromyogr Kinesiol, 2008, 18: 420–425.
13) Jung DY, Kim MH, Koh EK, et al.: A comparison in the muscle activity of the abductor hallucis and the medial longitudinal arch angle during toe curl and short foot exercises. Phys Ther Sport, 2011, 12: 30–35.
14) Anderson MK, Hall SJ, Martin M: Foundations of athletic training: Prevention, assessment and management. Lippincott Williams & Wilkins, 2004.
15) Prentice WE: Rehabilitation techniques in sports medicine. McGraw Hill Higher Education, 4th ed, 2009.
16) Christa LS: Three-dimensional treatment for scoliosis. Martindale Press, 7th ed, 2007, pp 74–75.
17) Wong YS: Influence of the abductor hallucis muscle on the medial arch of the foot: a kinematic and anatomical cadaver study. Foot Ankle Int, 2007, 28: 617–620.
18) Brody DM: Techniques in the evaluation and treatment of the injured runner. Orthop Clin North Am, 1982, 13: 541–558.
19) Arinici Incel N, Genc H, Erdem HR, et al.: Muscle imbalance in hallux valgus: an electromyographic study. Am J Phys Med Rehabil, 2003, 82: 345–349.
20) Benoit DL, Lamontagne M, Cerulli G, et al.: The clinical significance of electromyography normalization techniques in subjects with anterior cruciate ligament injury during treadmill walking. Gait Posture, 2003, 18:

56–63.
21) Bolgla LA, Uhl TL: Reliability of electromyographic normalization methods for evaluating the hip musculature. J Electromyogr Kinesiol, 2007, 17: 102–111.
22) Mulford D, Taggart HM, Nivens A, et al.: Arch support use for improving balance and reducing pain in older adults. Appl Nurs Res, 2008, 21: 153–158.
23) Finestone A, Novack V, Farfel A, et al.: A prospective study of the effect of foot orthoses composition and fabrication on comfort and the incidence of overuse injuries. Foot Ankle Int, 2004, 25: 462–466.
24) Mattila VM, Sillanpaa PJ, Salo T, et al.: Can orthotic insoles prevent lower limb overuse injuries? A randomized-controlled trial of 228 subjects. Scand J Med Sci Sports, 2010.
25) Brown GP, Donatelli R, Catlin PA, et al.: The effect of two types of foot orthoses on rearfoot mechanics. J Orthop Sports Phys Ther, 1995, 21: 258–267.
26) Franettovich M, Chapman A, Vicenzino B: Tape that increases medial longitudinal arch height also reduces leg muscle activity: a preliminary study. Med Sci Sports Exerc, 2008, 40: 593–600.
27) Kent-Braun JA, Le Blanc R: Quantitation of central activation failure during maximal voluntary contractions in humans. Muscle Nerve, 1996, 19: 861–869.