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Original Article

The Effect of an Inclined Ankle on the Activation of the Abductor Hallucis Muscle during Short Foot Exercise

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Abstract. [Purpose] The purpose of this study was to identify the effects of an inclined ankle on the activation of the abductor hallucis muscle during short foot exercises. [Subjects] We recruited 14 healthy volunteers who were free of pain, and did not suffer from arthritis or osteomuscular problems related to the foot or ankle. [Methods] The subjects performed short foot exercises and short inclined foot exercises with 30° passive ankle dorsiflexion. [Results] The exercise with an inclined foot showed a significantly larger activation of the abductor hallucis than that shown during the neutral short foot exercises. [Conclusion] These results suggest that passive ankle dorsiflexion during short foot exercise for strengthening the abductor hallucis is a more effective clinical treatment exercise.
Key words: Abductor hallucis, Inclined ankle, Short foot exercise

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INTRODUCTION

The medial longitudinal arch (MLA) is supported by the foot bone. The plantar muscles and tendons function as a shock absorber and influence gait efficiency[1)]. MLA is categorized into three types: flat feet, regular feet, and cavus feet[2)]. The causes of flat feet are numerous, and include the weakness of the abductor hallucis, which is an intrinsic muscle of the plantar surface of the foot[3)]. Foot exercise is used to reinforce the arch of the foot and strengthen the plantar muscles. There are many exercises for strengthening the abductor hallucis muscle, which is one of the intrinsic muscle supporting the MLA, for example: toe curls exercise, toe spread exercise, shin curls, and picking up objects[4)]. Recently, the short foot exercise has become more prevalent[4)]. It is performed by shortening the foot in the anterior-posterior direction with the forefoot and heel touch the floor without toe flexion[3)]. It was noted that after the short foot exercise was conducted, it was noted that there was an increase in the MLA angle[3)], and a reduction of center of pressure[5)]. Therefore, it has been assumed to be an effective method for MLA treatment and for strengthening the abductor hallucis muscle. Myers (2008) described how the plantar fascia and the short toe flexors are connected with the triceps surae (gastrocnemius) on the superficial back line[6)]. According to the passive length-tension relationship, passive tension in a stretched healthy muscle produces elastic forces[7)]. An inclined ankle with an elongated the triceps surae also generates larger intrinsic foot muscle tension. Therefore, the purpose of this study was to measure the effect of an inclined ankle on abductor hallucis muscle activation during the short foot exercise.

SUBJECTS AND METHODS

We recruited 14 healthy volunteers for this study. Individuals were excluded if they had arthritis, or had undergone an operation on, or amputation of the foot or ankle in the past 6 months. They were also excluded if they suffered from hallux valgus, hammer toe, or claw toe deformities. All selected subjects showed values the normal range (5–9 mm) in the navicular drop test[8)] and ankle range of motion (ROM). Ethical approval was obtained from Inje University Faculty of Health Science Human Ethics Committee, and all the subjects signed an informed consent form prior to their participation.

The participants' mean age was 24.71±5.12 years, their mean height was 166.21±8.96 cm, and their mean body mass was 58.21±9.42 kg. The surface EMG activities of the abductor hallucis were recorded by a MP150WSW data acquisition system (Biopac Systems, Santa Barbara, CA, USA). All the EMG signals were amplified, bandpass-filtered (20 Hz to 500 Hz), and sampled at 1,000 Hz using AcqKnoledge software, version 3.9.1. The EMG data were normalized to peak maximal voluntary isometric contraction (Peak %MVIC)[9)].

The subjects were instructed to keep an upright sitting posture on the chair, and performed two types of short foot

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exercises. One was the general type of short foot exercise performed on a flat floor (neutral SF), and the other the short foot exercise was performed with 30° passive ankle dorsiflexion provided by a tilting board for stretching the triceps surae (inclined SF). The short foot exercise was performed so that the metatarsal was drawn towards the heel without any toe flexion. Each task was repeated three times and maintained for 5 seconds. A 1 minute rest period was provided between the exercises.

Statistical analysis was performed using SPSS, version 17.0 (SPSS Inc., Chicago). The paired t-test was performed to determine significant differences in the activities of the abductor hallucis during the short foot exercises. Statistical significance was accepted for values of $p<0.05$.

RESULTS

The %MVIC activations of the abductor hallucis during the short foot exercises were 59.18±13.00% for the inclined short foot exercise, and 49.31±13.27% for the neutral short foot exercise (Table 1). The inclined short foot exercise showed a significantly larger activation than that of the neutral short foot exercise ($p<0.05$).

Table 1. %MVIC of the abductor hallucis during the neutral and inclined short foot exercises (n=14)

	Neutral SF Mean (SD)	Inclined SF Mean (SD)
Abductor hallucis	49.31 (13.27)	59.18 (13.00) *

SF: short foot exercise, SD: standard deviation
*$p<0.05$

DISCUSSION

Many previous studies have reported that the short foot exercise is an effective exercise for strengthening the MLA of the foot. Thus, this study investigated the effectiveness of an inclined ankle short foot exercise for strengthening the abductor hallucis, when compared to a general short foot exercise. The abductor hallucis is an intrinsic muscle within the MLA supporting muscles, and its electromyographic signal is easy to measure because of its superficial position.

We had a hypothesized that the length-tension relationship would exert an influence on the intrinsic muscle of the foot. Therefore, we performed an inclined short foot exercise with 30° passive ankle dorsiflexion to elongate the ticeps surae. Carlson et al. (2000) reported the angle of maximum passive ankle dorsiflexion was about 31 degrees[10], and we set the passive dorsiflexion angle set to 30 degrees. Our results show that the inclined short foot exercise showed a higher activation than that of the general short foot exercise.

Previous studies have investigated the passive length-tension relationship of various regions. Hoang et al. (2005) found a new method of non-invasively measuring the passive length-tension properties of the human gastrocnemius muscle in vivo[11]. It was the first in vivo study, but the foot plantar muscles were neglected. Also, research related to the foot arch has reported methods for strengthening the abductor hallucis[3–5]. However, that research used the neutral foot position, and did not consider the passive length-tension relationship of the ankle. Thus, our present suggests a more effective exercise method for abductor hallucis strengthening than passive ankle dorsiflexion for intensifying the foot intrinsic muscle activation.

Our study had several limitations. The sample size was too small, so our results cannot be generalized to all subjects. Also, the abductor hallucis is a small muscle, so the EMG signal may contain cross talk. Finally, the abductor hallucis does not represent all of the foot arch muscles, which consist of many other small intrinsic muscles.

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. [Medline]
2) 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. [Medline] [CrossRef]
3) 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. [Medline] [CrossRef]
4) Kim MH, Kwon OY, Kim SH, et al.: Comparison of muscle activities of abductor hallucis and adductor hallucis between the short foot and toe-spread-out exercises in subjects with mild hallux valgus. J Back Musculoskeletal Rehabil, 2013, 26: 163–168. [Medline]
5) Lynn SK, Padilla RA, Tsang KK: Differences in static- and dynamic-balance task performance after 4 weeks of intrinsic-foot-muscle training: the short-foot exercise versus the towel-curl exercise. J Sport Rehabil, 2012, 21: 327–333. [Medline]
6) Myers TW: Anatomy trains, 2nd ed. Churchill Livingstone, 2009.
7) Neumann DA: Kinesiology of the musculoskeletal system: Foundations for rehabilitation, 2nd ed. Mosby, 2010.
8) Brody DM: Techniques in the evaluation and treatment of the injured runner. Orthop Clin North Am, 1982, 13: 541–558. [Medline]
9) Bolgla LA, Uhl TL: Reliability of electromyographic normalization methods for evaluating the hip musculature. J Electromyogr Kinesiol, 2007, 17: 102–111. [Medline] [CrossRef]
10) Carlson RE, Fleming LL, Hutton WC: The biomechanical relationship between the tendoachilles, plantar fascia and metatarsophalangeal joint dorsiflexion angle. Foot Ankle Int, 2000, 21: 18–25. [Medline]
11) Hoang PD, Gorman RB, Todd G, et al.: A new method for measuring passive length-tension properties of human gastrocnemius muscle in vivo. J Biomech, 2005, 38: 1333–1341. [Medline] [CrossRef]