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A Comparison of Muscle Activities in the Lower Extremity between Flat and Normal Feet during One-leg Standing

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Abstract. [Purpose] This study examined the differences in muscle activation between flat and normal feet in the one-leg standing position which delivers the greatest load to the lower extremity. [Subjects] This study was conducted with 23 adults, 12 with normal feet and 12 with flat feet, with ages ranging from 21 to 30 years old, who had no neurological history or gait problems. [Methods] The leg used for one leg standing was the dominant leg of the subjects. The experimenter instructed the subjects to raise the non-dominant leg with their eyes open, and the subjects maintained a posture with the non-dominant leg's knee flexed at 90° and the hip joint flexed at 45° for six seconds. In the position of one-leg standing, a horizontal rod was set at the height of the waist line of the subjects who lightly placed two fingers of each hand on the rod to prevent inclination of the trunk to one side. Measurements were taken three times and the maximum value was used. A surface electromyogram (TeleMyo 2400T, Noraxon Co., USA) was used to measure muscle activities. [Results] We compared muscle activities between flat and normal foot, and the results show a significant difference between normal and flat feet in the muscle activity of the abductor hallucis muscle. [Conclusion] The subjects with flat feet had relatively lower activation of the abductor hallucis muscle than those with normal feet during one leg standing. We infer from this that the abductor hallucis muscle of flat foot doesn't work as well as a dynamic stabilizer, compared to a normal foot, during one leg standing.
Key words: Flat foot, Electromyography, One-leg standing

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INTRODUCTION

The foot and ankle joints play an important role in gait. Namely, the structure of foot is adapted for locomotion, and alignment of the foot plays an important role in standing and gait.

The foot also adapts to the type of floor, and it supports propulsion by providing ground reaction force as well as playing an important role in weight bearing through subtalar joint movement[1)]. Flat foot is a condition that is either congenital or acquired, and it has characteristics such as talus medial rotation, decreased medial arch height, and forefoot supination and abduction[2)]. Kinematic causes of flat foot have been explained by many researchers. It may occur due to dysfunction of the posterior tibial tendon, which is one of the important supporters of medial arch. It may also occur due to dysfunction of the spring ligament[3)], or injury of the plantar fascia[4)]. An overweight condition may also increase the susceptibility to flat foot; and in the case of children, the incidence of flat foot depends on age, and gender: the incidence of flat foot in girls is less than in boys as age increases[5)].

The height of the longitudinal arch of the foot is affected by pronation or supination and excessive pronation triggers flat feet. Flat feet cause tension in the muscles and fascias, and increase internal rotation of the hip joints and lumbar lordosis in a closed chain position. When the location of the pelvis is tilted to the side, scoliosis or a pathological condition of the lumbar spine is triggered, and such postural alteration of the lumbosacral complex increases the risk of low back pain[6)].

However, research on muscle activation between normal and flat feet has been insufficient. Accordingly, this study examined differences in muscle activation between flat and normal feet in the one-leg standing position which delivers the greatest load to the lower extremity.

SUBJECTS AND METHODS

This study was conducted with 23 adults, 12 with normal feet and 12 with flat feet, with ages ranging from 21 to 30 years old, who had no neurological history or gait problems.

Flat foot was checked by a foot pressure analysis device, Postural analysis (GPS400, Redbalance, Italy).

Evaluation of flat foot was performed using Strake's line and Marie's line as described by Clarke[7)]. Strake's line is the line passing through the medial border of the forefoot

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and the hindfoot, Marie's line is the line passing center of 3rd metatarsal bone and the hindfoot.

And we checked availability of flat foot with Strake's line and Marie's line. Normal foot is the condition in which the line of the medial arch passes lateral to Marie's line. Flat foot is line of medial arch passes medial to Marie's line. In this study, we provided a comfortable laboratory environment with a warm indoor temperature, and we obtained subjects' consent to participation prior to conducting the experiment.

The leg used for one leg standing was the dominant leg of the subjects. The experimenter instructed the subjects to raise their non-dominant leg with their eyes open, and the subjects maintained a posture with the non-dominant leg's knee flexed at 90° and the hip joint flexed at 45° for six seconds. In the position of one leg standing, a horizontal rod was set at the height of the waist line of the subjects who lightly placed two fingers of each hand on the rod to prevent inclination of the trunk to one side. Measurements were taken three times in each posture and the maximum value was used.

Subjects rested for 2 minutes between measurements in order to prevent muscle fatigue. We collected the data using wireless surface electromyography (TeleMyo 2400T, Noraxon Co., USA). The active electrodes comprised two stainless steel pads with a diameter of 11.4 mm, separated by a distance of 20 mm. Electromyograms were stored and analysed using software (TeleMyo 2400T system, USA). We used a sampling rate of 1,000 Hz with bandpass filtering from 20–450 Hz and notch filter processing at 60 Hz. Electromyography (EMG) was performed after depilating the electrode attachment areas with a razor, removing the horny layer with sand paper, and cleansing with an alcohol swab. To measure muscle activities in the lower extremity during one leg standing, electrodes were attached to the abductor hallucis, medial gastrocnemius, tibialis anterior, vastus medialis, vastus lateralis and rectus femoris.

The surface electrodes used were composed of three electrodes. The frequency range of the EMG signal was filtered between 20 and 500 Hz, and the sampling frequency was 1,024 Hz. We normalized the signal of each muscle with Maximal Voluntary Isometric Contraction (%MVIC) before comparing RMS values of muscle activities. Ages, heights and weights were compared using the independent t test. Measured data were analyzed using the independent t test and SPSS for Windows (version 17.0). Statistical significance was accepted for values of $p<0.05$.

Table 1. General characteristics of each group (%MVC)

	N (n=12)	F (n=11)
M/F	8/4	6/5
Height	169.0 ± 8.4	170.8 ± 8.3
Weight	65.4 ± 8.5	71.5 ± 19.5
Foot length (mm)	258.2 ± 4.3	256.3 ± 3.3
Ankle width (cm)	7.7 ±0.8	7.5 ±0.5

*p<0 .05, N: normal foot, F: flat foot

RESULTS

The general characteristics of the subjects are shown in Table 1. We compared lower limb muscle activities between flat and normal feet, and the results show a significant difference the activity of the abductor hallucis muscle ($p<0.05$) (Table 2).

DISCUSSION

We investigated the differences between the flat and normal feet during one-leg standing which delivers the greatest load to the lower extremity to look for risk factors in this study.

The abductor hallucis muscle is a muscle located below the medial longitudinal arch of the foot and stops at the medial side of the base of the proximal phalanx of the hallux. The function of this muscle is to provide dynamic stability of the medial longitudinal arch[8)]. In the present study, subjects with flat feet had lower activation of the abductor hallucis muscle than those with normal feet during one-leg standing.

We infer from this result that the abductor hallucis muscle of a flat foot doesn't work as well as a dynamic stabilizer, compared to a normal foot, during one-leg standing. Fiolkowski et al.[9)], confirmed that the abductor hallucis muscle affects the height of the navicular bone through a tibial nerve block. And Headlee et al.[10)], also confirmed that the height of navicular bone was depressed by fatigue of the abductor hallucis muscle.

The most common structural deformity of the flat foot is rearfoot varus. As a response to this deformity, the subtalar joint often overcompensates by excessively pronating[11)]. Similar compensation occurs as a result of forefoot varus, and an abnormal kinematic sequence between the tibia and femur may cause an increased "Q angle" at the knee and increased net lateral pull of the quadriceps or iliotibial band on the patella[11)]. We speculate that this is the reason why vastus lateralis muscle activation is higher in persons with flat feet.

This study verified that persons with flat feet have a reduced biomechanical ability for absorbing external impacts during activities of daily living, raising their risk of incur-

Table 2. Comparison of muscle activities between flat foot and normal foot during one-leg standing (%MVC)

	N (n=12)	F (n=11)
AH*	85.0 ± 22.7	59.9 ± 21.3
MG	30.7 ± 14.2	24.9 ± 11.9
TA	29.4 ± 20.0	23.3 ± 5.1
VM	26.2 ± 33.7	18.8 ± 22.5
VL	18.3 ± 17.4	24.1 ± 34.7
RF	12.7 ± 7.9	15.1 ± 9.6

*p<0 .05, N: normal foot, F: flat foot, AH: abductor hallucis, MG: medial gastrocnemius, TA: tibialis anterior, VM: vastus medialis, VL: vastus lateralis, RF: rectus femoris ring physical damage, compared to persons with normal feet. In order to resolve this problem, we judge that utilization of a supporter for supporting foot intrinsic muscles, such as the abductor hallucis muscle, or strengthening of the intrinsic muscles, would be effective.

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