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Immediate Effect of Short-foot Exercise on Dynamic Balance of Subjects with Excessively Pronated Feet

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Abstract. [Purpose] The aim of this study was to determine the immediate effect of short-foot exercise (SFE) on the dynamic balance of subjects with excessively pronated feet. [Subjects] This study included 18 subjects with excessively pronated feet (navicular drop $\geq$ 10 mm) selected using the navicular drop test. [Methods] The limit of stability (LOS) was measured to determine the changes in the dynamic balance from before and after SFE in the standing and sitting positions. [Result] After the SFE, LOS increased significantly in all areas, namely, the left, right, front, back, and overall. [Conclusion] SFE immediately improved the dynamic balance of subjects with excessively pronated feet. Subsequent studies will be conducted to examine the effects of SFE performed over the long term on postural stability.
Key words: Short-foot exercise, Limit of stability, Pronated feet

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INTRODUCTION

Balance is a process through which the center of gravity is maintained by the body's support base, and it has been measured by measurement of lower extremity function[1)]. Postural control is an automatic response of the visual, vestibular, and proprioception systems. These peripheral elements supply diverse information to the central nervous system, which on receiving the information, causes the appropriate muscle responses to maintain posture. The lower extremity chain is connected with the foot, ankle, knee, and hip joint. Of these, the feet are placed at the farthest point and acts as the support base; however, because they are rather small, it is difficult for them to maintain balance. Therefore, a small dynamic change in the foot, i.e., the support base, could affect the postural control of the entire body[2)]. With regard to the arch of the foot, the foot has a pronated and supinated structure, and it can affect proprioceptive inputs through the movement of joints, changes in the contact area, and muscle strategy for maintaining the stability of the support base[3–5)]. Flat feet have excessive subtalar joint pronation; in the case of flat feet, instability and damage to the lower extremity cause hypermobility and passive instability[5)], and more neurological control by the neuromuscular system is required to maintain stability and balance. Thus, while the feet are supporting the body weight, the instability resulting from a flat foot could cause pathomechanical problems as well as a compensating action in the close kinematic chain of the lower extremity, thereby hampering the body's balance.

Thus far, several balance training techniques have been applied for improving postural stability. Recently, short-foot exercise (SFE), which takes appropriate foot positioning into consideration, has been widely accepted by physiotherapists. Janda and VaVrova[6)] found that SFE contracted the intrinsic muscles of the foot to increase the inner arch of the foot, thereby shortening the longitudinal arch of the foot. They stated that SFE improved the position of body segments and the stability of the body in the standing position by increasing afferent inputs from the bottom of the foot. They also stated that SFE is the first step in sensory motor training (proprioceptive training) and can improve proprioception and postural stability if applied along with other exercises. In a study on normal subjects, Lynn et al.[7)] reported that SFE for 4 weeks significantly decreased the mediolateral center of pressure (COP) movement during the dynamic balance test. Drewes[8)] also reported that daily SFE for 4 weeks improved self-reported function and the outcomes in two other function tests. However, few studies have been conducted on the direct effects of SFE postural stability, although studies on SFE have proposed that this exercise strengthens the intrinsic foot muscle and improves the functional performance of the lower extremity. Therefore, the aim of this study was to determine the immediate effect of SFE on the dynamic balance of subjects with excessively pronated feet.

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SUBJECTS AND METHODS

This study included 18 subjects with excessively pronated feet (navicular drop ≥ 10 mm) who were selected through the navicular drop test[9]. Their average age, weight, and height were 26.10 ± 5.26 year, 64.00 ± 14.91 kg, and 165.02 ± 7.96 cm, respectively. None of the subjects had experienced any pathologic symptoms in the feet and legs or gait problems for the last 6 months, and none had any history of operation on the lower extremities. Further, they also had no history of neurological disease or vestibular dysfunction. Informed consent was obtained from each subject, and subjects were not exposed to any risk of harm or physical discomfort in this study. For the SFE, the subjects were instructed to pull the first metatarsal head toward the heel without toe flexion and maintain this for 5 seconds in order to increase the medial longitudinal arch. The SFE consisted of passive, active-assistive, and active movements in the given order while sitting and standing. Each exercise had 3 sets, and the sets were repeated 5 times. Two minutes of rest was allowed after every set. Dynamic balance was examined using the limit of stability (LOS) test with the BioRescue system (RM Ingenierie, Rodez, France). In the LOS test, the subjects moved the COP in 8 directions (left, right, front, back, left front, left back, right front, and right back) to the furthest possible extent while they stood on the support base. The sway area generated by the COP was divided into the surface areas of the 4 directions (left, right, front, and back) and entire area. The LOS test was conducted before the SFE, and the participants revisited 1 week later to be retested on the LOS after the SFE. PASW for Windows (Ver. 19.0) was used for data collection, and a paired t-test was used to compare the results of the LOS test before and after the SFE.

RESULTS

Table 1 shows the surface area values for each direction in which the COP was moved in the LOS test. After the SFE, the surface areas for the left, right, front, and back increased significantly compared with the corresponding values before the SFE ($p < 0.05$). Further, the value of the entire surface area of the COP movement increased significantly after the SFE ($p < 0.05$).

Table 1. Comparison of surface area in the LOS between before and after SFE (Unit: mm^2)

	Before SFE	After SFE
Left*	2,408.1±989.8	3,259.1±861.1
Right*	2,221.9±845.8	2,977.6±1,074.4
Forward*	2,970.2±1,382.5	4,085.6±1,517.3
Back*	1,659.9±600.7	2,151.2±758.4
Total*	4,629.9±1,794.3	6,236.8±1,838.3

*$p<0.05$; mean ± SD, SFE: short-foot exercise, LOS: limit of stability

DISCUSSION

The aim of this study was to determine the immediate effect of SFE on the dynamic postural control of unstable, hyperpronated feet. Our results regarding measurement of the dynamic balance after SFE using the LOS test showed that the surface areas for the left, right, front, and back directions as well as the entire surface area increased. The LOS is a sway boundary for the area within which a person can willingly maintain the center of gravity in the support base surface. Therefore, an increase in the LOS indicates an equivalent improvement in postural stability. In a similar previous study on normal healthy adults, Lynn et al.[7] reported that compared with a towel curl exercise group and control group, their SFE group showed a substantially greater reduction in the mediolateral COP movement of the nondominant legs after 4 weeks of exercise while undergoing the dynamic balance test on a force plate. They speculated that the explanation for this was an improvement in the integrity of the medial longitudinal arch induced by the intrinsic foot muscle strengthening resulting from the SFE. In contrast, Rothermel et al.[11] reported that in a static stability test conducted on normal healthy adults, the COP excursion velocity decreased substantially more in a traditional balance training group than an SFE balance training group and control group after 4 weeks. They stated that the traditional balance training group concentrated on maintaining balance only, whereas the SFE balance training group concentrated too much on maintaining the SFE positions, which interfered with their involuntary neurological activity.

The present study showed that dynamic stability improved immediately after the SFE because of an increase in LOS. The reason for this was that the SFE stimulated the proprioceptors at the bottom of the foot, thereby increasing afferent stimulation and consequently, improving stability and voluntary muscle activities[6]. In particular, the cutaneous receptor at the bottom of the foot was considered to be stimulated[10]. In other words, pulling the metatarsal heads of the foot toward the calcaneus further increased the pressure of the contact area of the foot on the floor, thereby intensifying the cutaneous stimulation.

This study has some limitations. First, it included a relatively small sample. Second, subjects with excessively pronated feet but no symptoms were selected. Third, the intervention period was rather short. In the future, a study will be conducted with patients who have lower extremity dysfunction due to flat feet in order to examine postural stability after long-term SFE.

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