The Effects of the Visual Feedback Short Foot Exercise on Foot Alignment in Adults with Flexible Flatfoot

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Abstract--- *Flexible flatfoot occurs when the medial longitudinal arch collapses when weight bearing and returns to a normal arch when weight is removed with forefoot abduction and hindfoot valgus. This can cause pathological problems in the alignment of the lower extremities and the entire body. Recently, the short foot exercise has drawn attention as an intervention for flexible flatfoot. The purpose of this study is to investigate the effects of the short foot exercise with and without visual feedback on foot alignment in adults with flexible flatfoot. The subjects were 24 adults with flexible flatfoot. They were randomly assigned to a visual feedback short foot exercise group and short foot exercise group. Each group performed the exercise five times a week for six weeks. Foot alignment was measured using the picture archiving and communication system, and four radiological measurements were taken from lateral and antero-posterior x-rays(calcaneal inclination angle, lateral talocalcaneal angle, antero-posterior talocalcaneal angle and antero-posterior talometatarsal angle). In the visual feedback short foot exercise group, the calcaneal inclination angle, lateral talocalcaneal angle, antero-posterior talocalcaneal angle and antero-posterior talometatarsal angle showed significant differences. The short foot exercise group showed significant differences for the calcaneal inclination angle and the antero-posterior talometatarsal angle. However, there were no significant differences between the groups. These results suggest that the short foot exercise is an effective exercise for young adults with flexible flatfoot in terms of changing foot alignment. Additionally, exercise with visual feedback is more effective for complete alignment of view, including the hindfoot.*

Keywords--- *Flexible Flatfoot, Short Foot Exercise, Visual Feedback, Foot Intrinsic Muscles, Foot Alignment.*

I. INTRODUCTION

Flexible flatfoot occurs when the medial longitudinal arch is lowered when weight bearing and returns to normal when weight is removed[1]. The characteristics of flatfoot are a drop in the medial longitudinal arch, forefoot abduction and hind foote version[2]. The condition changes soft tissue alignment, causing knee pain, cartilage damage and tibial stress syndrome[3]. Also, the force on the medial part of the foot is increased, resulting in proximal abnormality, tibial internal rotation, hip joint internal rotation, knee joint valgus deformity, pelvic anterior tilting and lumbar hyperlordosis[4-6]. People who have flexible flatfoot do not show subtalar joint inversion and talus dorsiflexion, during the latter half of the stance phase in gait, leaving the foot relatively unstable, this leads to foot and lower leg fatigue[1]. The normal biomechanics of the medial longitudinal arch support the foot stability and minimize the flattening of the arch; therefore, structures contributing to the arch stability have to be strengthened[7].

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The intrinsic foot muscles provide support for the medial arch of the foot and prevent foot hyperpronation during static stance[8, 9]. The fatigue of the foot intrinsic muscles leads to an increase in foot pronation[10]. There are many exercise methods for strengthening the intrinsic foot muscles, including the toe towel curl exercise, picking up objects exercise and short foot exercise[11]. Recently, the short foot exercise has been used to train intrinsic foot muscles but not extrinsic foot muscles[12]. The sensory information from the sole affects important reactions and improves muscular sense and posture[13].

Biofeedback has been used in rehabilitation to facilitate normal movement patterns[14]. It provides real-time data and is efficacious in treating a variety of medical conditions[15]. Feedback using commonly used visual signals sends conscious information about the body position in relation to the environment to the central nervous system to create an appropriate motor response[16].

There is little research on the short foot exercise, and previous studies of this exercise approved changes of navicular drop heights, balance and gait. Although the positive results of navicular drop test suggest changes in foot alignment, no study has been conducted to identify whole foot alignment changes. Thus, the purpose of the current study is to investigate the effects of the short foot exercise on foot alignment in adults with flexible flatfoot; these effects are compared with the short foot exercise with visual feedback. The hypotheses are that the short foot exercise changes the whole foot alignment and that the visual feedback short foot exercise is more effective in adults with flexible flatfoot.

II. MATERIALS AND METHODS

A. Subjects

The subjects of this study were 24 adults. The detailed selection criteria were as follows: 1) those who tested positive on the Feiss Line test; 2) those who had not had any previous orthopedic surgery or treatment on lower extremities; 3) those who did not have visual field defect and vestibular disorders; 4) those who did not have inflammatory arthritis; 5) those who had not recently performed continuous muscle strengthening. All subjects were fully informed about the purpose and methods of this study and signed the study consent form voluntarily. This study was approved by the Bioethics Committee of Daegu University(No : 1040621-201702-HR-029-02).

B. Experimental design

The foot radiography of all subjects was measured using a picture archiving and communication system (PACS) for the baseline assessment of alignment. All subjects received education from a physiotherapist about the short foot exercise with bare feet. The physiotherapist grasped the foot, and elevated the medial arch and pushed the metatarsal head without toe flexion. Subjects were randomly divided into a visual feedback short foot exercise group(VSFG, n=12) and short foot exercise group(SFG, n=12). The exercise program was gradually strengthened. Both groups were conducted under the same conditions other than the presence of omission of visual feedback: 50 minutes a session, five times a week, for six consecutive weeks. After six weeks, a post assessment was conducted. Alignment of the foot in all subjects was measured with the same method as the baseline assessment.

C. Intervention

1) Exercise program

The exercise program consisted of a warm-up, the main exercise and a cool-down. The subjects performed the short foot exercise while sitting, standing, standing on one leg for the entire exercise period. Additionally, during weeks one and two, standing in a line and weight shift were performed while maintaining a short foot. During weeks three and four, PNF upper extremity D1 and D2 patterns and leg kicking were performed. During weeks five and six, half squats, one leg squats and lunges were performed. Warm-ups and cool-downs engaged the triceps surae muscles, quadriceps femoris, and hamstring muscles.

2) Visual feedback

For real-time visual feedback to VSFG, a mat scan system(Tekscan Inc., South Boston, MA, USA)(Figure1) was used. Before exercise, subjects assumed the short foot position on the mat by looking at the monitor and maintained pressure during exercise. The other conditions were the same.

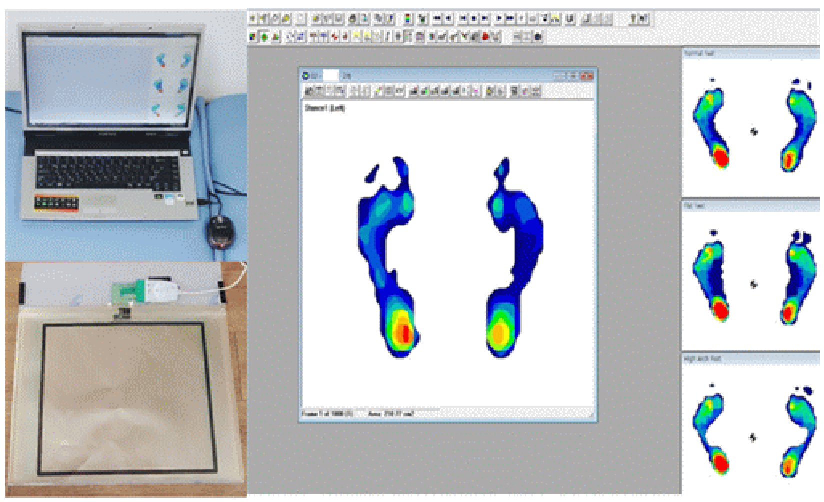

Figure 1: Mat scan system

Statistical analyses

The foot radiography of all subjects was measured using the picture archiving and communication system(PACS), and four radiological measurements were taken from lateral(calcaneal inclination angle and lateral talocalcaneal angle)(Figure2) and antero-posterior x-rays (antero-posterior talocalcaneal angle and antero-posterior talometatarsal angle)(Figure3) to compare differences in foot alignment.

All the data were analyzed with SPSS 23.0 ver. for Windows(SPSS Inc, Chicago, IL). Means and standard deviation of the general characteristics and variables of the subjects were calculated, and the Shapiro-Wilk test was used for normality. A paired t-test was conducted to confirm the difference in foot alignment before and after each group exercise. An independent t-test was conducted to confirm the difference between groups. The statistical significance level was set to 0.05.

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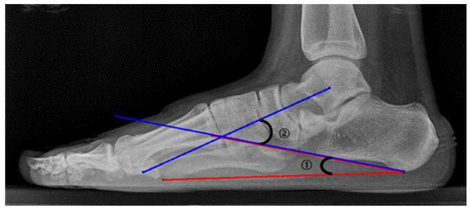

Figure 2: Lateral foot alignment ①Calcaneal inclination angle ②Lateral talocalcaneal angle

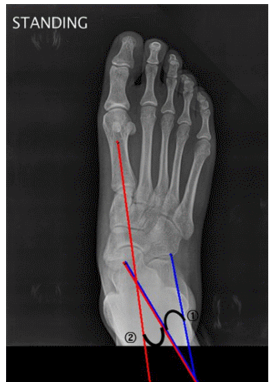

Figure 3: Antero-posterior foot alignment ①Antero-posterior talocalcaneal angle② Antero-posterior talometatarsal angle

III. RESULTS

The homogeneity test showed that the two groups were homogeneous because there were no significant differences(P>0.05)(Table1).

The short foot exercise group showed significant differences(P<0.05) for the calcaneal inclination angle and the antero-posterior talometatarsal angle. In the visual feedback short foot exercise group, the calcaneal inclination angle, lateral talocalcaneal angle, antero-posterior talocalcaneal angle and antero-posterior talometatarsal angle showed significant differences(P<0.05). However, there were no significant differences between the groups(P>0.05)(Table2)(Table3).

Table 1: General characteristics of subjects

	VSFG [a)]	**SFG** [b)]	**t**	***P***
Gender(M/F)	6/6	6/6		
Age(years)	22.66±0.98[c)]	23.50±1.97	-1.30	.20
Height(㎝)	167.09±7.92	168.25±9.15	-.33	.74
Weight(kg)	66.18±13.20	65.69±17.30	.07	.93
Navicular drop test(㎜)	12.83±4.10	12.50±2.61	.23	.81

[a)],VSFG: Visual feedback short foot exercise group
[b)],SFG: Short foot exercise group
[c)],Mean ± standard deviation, *P<0.05*

Table 2: The comparison of lateral foot alignment (unit: degree)

Angle	Group	Pre	Post	Difference value	t	*P*
Calcaneal inclination angle	VSFG [a)]	14.90±4.30[c)]	16.94±4.51	2.04±1.34	-5.26	.00*
	SFG [b)]	16.30±3.59	17.45±3.42	1.14±0.97	-4.07	.00*
	T	-.86		1.87		
	P	.39		.07		
Lateral talocalcaneal angle	VSFG [a)]	36.66±4.04	33.91±3.83	-3.90±6.83	4.16	.00*
	SFG [b)]	37.70±6.12	33.79±4.57	-3.49±7.66	1.98	.07
	T	.15		-.14		
	P	.87		.89		

[a)],VSFG: Visual feedback short foot exercise group
[b)],SFG: Short foot exercise group
[c)],Mean ± standard deviation, * *P<.05*

Table 3: The comparison of antero-posterior foot alignment (unit: degree)

Angle	Group	Pre	Post	Difference value	t	*P*
Antero-posterior talocalcaneal angle	VSFG [a)]	28.14±7.25[c)]	24.79±8.70	-3.34±3.58	3.23	.00*
	SFG [b)]	26.39±7.61	24.28±6.89	-2.10±8.93	.81	.43
	t	.57		-4.48		
	P	.56		.65		
Antero-posterior talometatarsal angle	VSFG	19.52±10.30	12.29±9.14	-7.23±7.31	3.42	.00*
	SFG	17.27±4.97	11.11±4.49	-6.16±6.35	3.35	.00*
	t	.68		-.38		
	P	.50		.70		

[a)],VSFG: Visual feedback short foot exercise group
[b)],SFG: Short foot exercise group
[c)],Mean ± standard deviation, * *P<.05*

IV. DISCUSSION

The lowered medial longitudinal arch of the foot leads to the forefoot abduction and hindfoot eversion. The intrinsic foot muscles play a critical role in maintaining the arch, and strengthening these muscles can prevent possible deformity and pathology. Therefore, this study was conducted to investigate the effects of the popular short foot exercise on foot alignment in adults with flexible flatfoot and the difference effects of the exercise when conducted with and without visual feedback.

The first characteristic of flexible flatfoot is a lowered longitudinal arch. The calcaneal inclination angle on the lateral view was measured to evaluate this change. The normal range of this angle is between 15 and 21, that is decreased in the case of flatfoot[17, 18].

This angle improved significantly in both groups and included normal range. There were no significant differences between groups, but the exercise group with visual feedback showed a greater effect. Some studies have reported that navicular drop is decreased short foot exercise for four weeks[19, 20]. Therefore, this exercise intervention has a significant effect on normalizing and supporting the medial longitudinal arch.

The second characteristic of flexible flatfoot is forefoot abduction. The talometatarsal angle on the antero-posterior view was measured to evaluate this change[17,21]. The normal range of this angle is below 15, and that is increased in the case of flatfoot. This angle improved significantly in both groups and included normal range. There were no significant differences between groups, but the exercise group with visual feedback showed a greater effect. A study reported that abductor hallucis activation was significantly greater in the short foot exercise than toe toe curl exercise[11]. It is suggested that this exercise intervention is effective on strengthening intrinsic muscles but not extrinsic muscles and improving forefoot abduction by increasing activation of the abductor hallucis, that is the first layer of intrinsic foot muscles.

The third characteristic is hindfoot eversion. The talocalcaneal angle on the lateral and antero-posterior view was measured to evaluate this change. A study found that this angle is increased in cases of flatfoot[22]. The visual feedback exercise group showed significant effects, but there were no significant effects between groups. Although there were no significant effects, these results suggest that the short foot exercise is effective in improving the hindfoot eversion in the visual feedback exercise.

Several studies have supported the effects of the short foot exercise on navicular position, but no study has been conducted on other alignments of the foot. This study proves that the short foot exercise can change not only the medial longitudinal arch, but also forefoot and hindfoot alignment.

Mechanoreceptors are mostly concentrated in the sole, sacroiliac joint and cervical joint; therefore, the short foot exercise improve afferent sensitivity[23]. Muscle activity is affected when the plantar sensory input is altered[24]. Visual sensory input does not appear to have a great effect; because the short foot exercise provides enough sensory input. Even though there were no significant differences between groups that performed the exercise with or without visual feedback, the results of this study suggest the short foot exercise is effective for changing the forefoot and medial longitudinal arch, and exercises with visual feedback are effective for complete alignment of view, including the hindfoot.

There were several limitations to the present study. It is difficult to generalize the study results due to the small number of subjects. In addition, the assessment was only performed on subjects' dominant feet. Future studies need to assess more subjects and both feet in order to determine and compare the effects of the exercises.

In conclusion, this study suggests that short foot exercise can be useful for improving foot alignment in case of flexible flatfoot, and the visual feedback short foot exercise is a more effective method.

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