



Original Article

Effects of orthotic insoles on adults with flexible flatfoot under different walking conditions

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Abstract. [Purpose] This study was to evaluate the effects of orthotics on adults with flexible flatfoot when wearing orthotic insoles while walking on horizontal ground, walking up and down stairs and to determine if flexible flatfoot needs treatment. [Subjects and Methods] Fifteen college students with flexible flatfoot and fifteen college students with normal feet were recruited. First, load rate and contact area were measured by RSscan force plate when the subjects were walking on horizontal ground, walking up and down 10 cm and 20 cm stairs. Then the subjects with flexible flatfoot were instructed to wear orthotic insoles for 3 months, and plantar pressure was measured again. Finally, the data were subjected to repeated measures ANOVA. [Results] After treatment for 3 months, the plantar pressure of flatfoot was significantly improved. In addition, the data of the subjects with normal feet and flatfoot were significantly influenced by walking down 10 cm or 20 cm stairs. [Conclusion] Orthotic insoles could significantly improve the plantar pressure of flatfoot. Additionally, the arches of subjects with normal feet and flatfoot can be significantly deformed when walking down stairs. Therefore, it is essential for subjects with flexible flatfoot to wear orthotic insoles to avoid needless injury.

Key words: Flexible flatfoot, Plantar pressure, Orthotic insoles

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INTRODUCTION

Flatfoot, also called pes planus or low arch, refers to a condition in which the medial longitudinal arch is flat or missing and is one of the common deformities included in lower limbs diseases¹⁾. Because the alignment of the foot is in disorder²⁾, changes in foot structure occur that cause other conditions like ankle arthritis³⁾, pollex valgus⁴⁾, and foot pain⁵⁾.

Flatfoot can be divided into rigid flatfoot and flexible flatfoot by its structure⁶⁾. The arch of the foot in the former case is always flat when one is in a weight-bearing or non-weight-bearing position, and it will result in pain or other discomfort⁷⁾. However, the arch of the foot in the latter case is flat only in a weight-bearing position; in a non-weight-bearing position, the foot arch is the same as in the case of a normal foot⁸⁾.

Due to the fact that the arch is always missing in the case of rigid flatfoot, surgical treatment is generally needed to correct the structure of the bones⁹⁾. In contrast, the arch in the case of flexible flatfoot is so plastic that conservative physiotherapy can achieve a corrective effect¹⁰⁾. However, sufficient attention has not been paid to the conservative treatment of flexible flatfoot. Furthermore, whether flexible flatfoot needs treatment has always been controversial.

The orthotic insole is a tool used in physiotherapy; however, its effects have not been clarified. Previous studies have only estimated conservative effects of orthotic on the plantar pressure of individuals with flatfoot on horizontal ground^{11–13)}, how plantar pressure data vary when walking up and down stairs has not been studied. Therefore, this study measured the data of subjects under different walking conditions to evaluate the effects by wearing orthotic insoles and further determine if conservative treatment is needed.

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SUBJECTS AND METHODS

This study was approved by the Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University, and informed consent was provided by the subjects.

Fifteen adults with flexible flatfoot and fifteen adults with normal feet were recruited after determining their status by collecting their foot prints using an RSscan force plate. All subjects were college students who had not had any lower limb diseases in the past 6 months. There was no significant difference in age, height, weight, or foot length between subjects with flexible flatfoot and subjects with normal feet. For the subjects with flatfoot, the arch was missing in a load-bearing position, the proportion of the midfoot print between the hollow area and solid area was 1/2, or the hollow area was missing. For the subjects with normal feet, the arch was always present, and the proportion was 2/1.

This study used an RSscan force plate (RS footscan USB 7), which has an area of 40 × 50 cm and 4,096 sensors; this device can measure dynamic plantar pressure. The foot was automatically divided into 10 parts by the plate, including toe 1, toes 2–5, the first metatarsal bone, the second metatarsal bone, the third metatarsal bone, the fourth metatarsal bone, the fifth metatarsal bone, the mid foot, the medial heel, and the lateral heel. Due to the arch of the midfoot being the main difference between a flatfoot and normal foot¹⁴, this study focused on only the load rate and contact area of the midfoot.

After performing walking exercise several times, the subjects were asked to walk on horizontal ground and to walk up or down 10 cm or 20 cm stairs at one step per second in socks (the same socks for each subject) while not wearing shoes. Under each walking condition, the RSscan force plate was used to record data for load rate and contact area. Each variable was measured 3 times, and the mean value was calculated. Then the subjects with flexible flatfoot were asked to wear shoes (the same shoes for each subject) containing the orthotic insoles 8 hours per day for 3 months, and plantar pressure was measured again after treatment. Once recording of data was complete, the data were divided into the following 3 groups: flatfoot before treatment, flatfoot after treatment, and normal feet. Each group was further divided according to 5 walking conditions: walking on horizontal ground, walking up 10 cm stairs, walking up 20 cm stairs, walking down 10 cm stairs, and walking down 20 cm stairs. Repeated measures ANOVA was performed using spss 13.0, and the level of significance was set at $p < 0.05$. The 95% confidence interval (CI) ($p < 0.05$) was considered statistically significant. The 5 walking conditions were considered within-subjects variables, and the 3 groups were considered between-subjects factors.

This study measured the dynamic load rate and contact area by RSscan force plate in subjects walking under different conditions. The load rate (in N/ms) can be used to indicate the load-bearing ratio for various regions of the foot per millisecond¹⁵. The contact area can be used to indicate the area of contact between various regions of the foot and the ground, and it is shown in square centimeters¹⁶. The values for both of these variables are larger in the midfoot in individuals with flatfoot compared with those with normal feet¹⁷. Because the arch of the foot is decreased in individuals with flatfoot in a weight-bearing position, the structure of the bones of the foot is further deformed, which makes both the contact area and load rate of the midfoot larger.

The orthotic insoles in this study were made of an EVA resin material that was a copolymer of ethylene and vinyl acetate. The thickness of foot arch was 2.6 cm, and the thickness of fore foot and heel was 0.4 cm.

RESULTS

After treatment, load rate and contact area were significantly improved in subjects with flexible flatfoot. In addition, there were significant differences in load rate and contact area between before and after treatment ($p < 0.01$). However, the posttreatment data were still significantly different from those of subjects with normal feet ($p < 0.01$) (Tables 1 and 2).

Additionally, there was no intersection of 95% CIs between before and after treatment under any of the walking conditions. However, the 95% CIs for the subjects with flatfoot after treatment and those with normal feet did intersect under the conditions of walking down 10 cm and 20 cm stairs (Tables 3 and 4).

All the results indicated that although there was still a difference between subjects with flatfoot after treatment and those with normal feet, the data for load rate and contact area were significantly corrected under the different conditions, especially when walking down stairs. In other words, the data of the subjects with flatfoot changed after treatment, becoming more similar to the data of the subjects with normal feet.

Furthermore, the 95% CIs for walking down stairs did not intersect with those for any other walking conditions (Tables 3 and 4). This showed that the arches of the subjects with normal feet, in addition to those with flexible flatfoot, were deformed when walking down 10 cm stairs or 20 cm stairs.

DISCUSSION

The present study showed that the load rate and contact area of the subjects with flexible flatfoot were larger than those of the subjects with normal feet, which was consistent with previous studies^{18–20}. However, the data revealed that these variables were corrected effectively after 3 months of treatment consisting of wearing orthotic insoles. The results could be explained by the orthotic insoles increasing the arch height of the foot and correcting the alignment of foot bones, which

Table 1. Load rates for the 3 groups

	Group	Group	Mean difference	Std. error	95% confidence interval for difference (2)	
					Lower bound	Upper bound
Left foot	Before	Before				
		After	0.50*	0.17	0.17	0.84
		Normal	1.18*	0.17	0.84	1.51
	After	Before	-0.50*	0.17	-0.84	-0.17
		After				
		Normal	0.68*	0.17	0.34	1.01
	Normal	Before	-1.18*	0.17	-1.51	-0.84
		After	-0.68*	0.17	-1.01	-0.34
		Normal				
Right foot	Before	Before				
		After	0.67*	0.16	0.35	0.99
		Normal	1.09*	0.16	0.77	1.41
	After	Before	-0.67*	0.16	-0.99	-0.35
		After				
		Normal	0.42*	0.16	0.10	0.74
	Normal	Before	-1.09*	0.16	-1.41	-0.77
		After	-0.42*	0.16	-0.74	-0.10
		Normal				

Based on estimated marginal means.

*The mean difference is significant at the 0.05 level.

Before: flatfoot before treatment; After: flatfoot after treatment; Normal: normal feet

Table 2. Contact areas for the 3 groups

	Group	Group	Mean difference	Std. error	95% confidence interval for difference (2)	
					Lower bound	Upper bound
Left foot	Before	Before				
		After	10.65(*)	0.86	8.90	12.39
		Normal	12.60(*)	0.86	10.85	14.34
	After	Before	-10.65(*)	0.86	-12.39	-8.90
		After				
		Normal	1.95(*)	0.86	0.20	3.69
	Normal	Before	-12.60(*)	0.86	-14.34	-10.85
		After	-1.95(*)	0.86	-3.69	-0.20
		Normal				
Right foot	Before	Before				
		After	8.16(*)	0.49	7.16	9.15
		Normal	9.93(*)	0.49	8.93	10.92
	After	Before	-8.16(*)	0.49	-9.15	-7.16
		After				
		Normal	1.77(*)	0.49	0.77	2.77
	Normal	Before	-9.93(*)	0.49	-10.92	-8.93
		After	-1.77(*)	0.49	-2.77	-0.77
		Normal				

Based on estimated marginal means.

*The mean difference is significant at the 0.05 level.

Before: flatfoot before treatment; After: flatfoot after treatment; Normal: normal feet

Table 3. Load rates for the 5 walking conditions

	Group	Conditions	Mean difference	Std. error	95% confidence interval for difference (2)	
					Lower bound	Upper bound
Left foot	Before	Ground	1.7	0.1	1.6	1.9
		Up 10 cm stairs	1.7	0.1	1.5	1.8
		Up 20 cm stairs	1.6	0.1	1.5	1.7
		Down 10 cm stairs	3.4	0.2	3.0	3.8
		Down 20 cm stairs	5.2	0.3	4.6	5.8
	After	Ground	1.4	0.1	1.3	1.5
		Up 10 cm stairs	1.3	0.1	1.2	1.5
		Up 20 cm stairs	1.3	0.1	1.2	1.4
		Down 10 cm stairs	2.3	0.2	2.0	2.7
		Down 20 cm stairs	3.5	0.3	2.9	4.1
	Normal	Ground	0.9	0.1	0.7	1.0
		Up 10 cm stairs	0.7	0.1	0.6	0.9
		Up 20 cm stairs	0.6	0.1	0.5	0.7
		Down 10 cm stairs	1.8	0.2	1.4	2.2
		Down 20 cm stairs	3.7	0.3	3.1	4.3
Right foot	Before	Ground	1.6	0.1	1.5	1.7
		Up 10 cm stairs	1.5	0.1	1.4	1.6
		Up 20 cm stairs	1.5	0.1	1.4	1.6
		Down 10 cm stairs	3.1	0.2	2.8	3.5
		Down 20 cm stairs	4.8	0.3	4.1	5.4
	After	Ground	1.2	0.1	1.1	1.4
		Up 10 cm stairs	1.2	0.1	1.1	1.3
		Up 20 cm stairs	1.2	0.1	1.0	1.3
		Down 10 cm stairs	2.2	0.2	1.9	2.6
		Down 20 cm stairs	3.3	0.3	2.7	3.9
	Normal	Ground	0.8	0.1	0.7	0.9
		Up 10 cm stairs	0.7	0.1	0.6	0.8
		Up 20 cm stairs	0.6	0.1	0.5	0.7
		Down 10 cm stairs	1.8	0.2	1.5	2.2
		Down 20 cm stairs	3.1	0.3	2.5	3.7

Before: flatfoot before treatment; After: flatfoot after treatment; Normal: normal feet

could further improve plantar pressure²¹). With the increase in the height of foot arch, the weight-bearing sites were changed from the midfoot to the fore foot and heel. Therefore, the contact area and load rate of the midfoot were decreased. However, due to the limited time of orthotic treatment, there was still a significant difference between the subjects with flatfoot after treatment and those with normal feet.

Previous studies only focused on the effects of orthotics on plantar pressure on horizontal ground^{18–20}). None had estimated the effects of orthotics on plantar pressure while walking up and down stairs. In this study, it was observed that orthotic insoles could correct the plantar pressure of subjects with flatfoot not only on horizontal ground, but also when walking up and down stairs. This may be because the orthotics were able to correct the abnormal structure of the foot²²), suppress the eversion of the talocalcaneal joint²³), and further improve the joint angles of the lower limbs while walking up and down stairs.

It should be noted, however, that the highest values for load rate and contact area were for walking down 20 cm stairs and that the second highest values were for walking down 10 cm stairs. This may be due to the fact that when someone is going down stairs, the plantar pressure of the midfoot is affected not only by the body weight but is also affected by the acceleration of gravity, which causes greater loading of the midfoot²⁴). Therefore, when walking down stairs, the plantar pressure became larger with the increase in stair height.

It should also be noted that the values for load rate and contact area when walking down stairs were significantly larger than when walking on horizontal ground or up stairs in both groups of subjects. This shows that when walking down stairs, the arch of the foot is deformed badly not only in subjects with flatfoot but also in those with normal feet. In individuals with normal feet, the arch of the foot needs a certain amount of elasticity to protect plantar vessels and nerves from compression²⁵); however, the arch can be influenced by the impact of the foot with the stairs when walking down stairs. In individuals with

Table 4. Contact areas for the 5 walking conditions

	Group	Conditions	Mean difference	Std. error	95% confidence interval for difference (2)	
					Lower bound	Upper bound
Left foot	Before	Ground	52.4	0.5	51.4	53.5
		Up 10 cm stairs	52.1	0.5	51.0	53.1
		Up 20 cm stairs	51.7	0.5	50.7	52.7
		Down 10 cm stairs	55.2	0.7	53.8	56.7
		Down 20 cm stairs	58.6	1.0	56.6	60.5
	After	Ground	42.0	0.5	40.9	43.1
		Up 10 cm stairs	41.8	0.5	40.7	42.9
		Up 20 cm stairs	41.8	0.5	40.8	42.8
		Down 10 cm stairs	44.8	0.7	43.4	46.3
		Down 20 cm stairs	46.3	1.0	44.3	48.2
	Normal	Ground	39.3	0.5	38.2	40.3
		Up 10 cm stairs	38.7	0.5	37.6	39.8
		Up 20 cm stairs	38.3	0.5	37.3	39.3
		Down 10 cm stairs	43.3	0.7	41.8	44.7
Down 20 cm stairs		47.4	1.0	45.5	49.4	
Right foot	Before	Ground	50.2	0.4	49.4	51.0
		Up 10 cm stairs	50.1	0.4	49.3	50.9
		Up 20 cm stairs	50.0	0.4	49.1	50.7
		Down 10 cm stairs	53.0	0.4	52.3	53.7
		Down 20 cm stairs	55.8	0.4	54.9	56.6
	After	Ground	42.2	0.4	41.4	42.9
		Up 10 cm stairs	41.8	0.4	41.0	42.6
		Up 20 cm stairs	41.8	0.4	41.1	42.6
		Down 10 cm stairs	45.0	0.4	44.3	45.8
		Down 20 cm stairs	47.4	0.4	46.6	48.2
	Normal	Ground	40.1	0.4	39.3	40.9
		Up 10 cm stairs	39.6	0.4	38.8	40.4
		Up 20 cm stairs	39.4	0.4	38.6	40.2
		Down 10 cm stairs	44.0	0.4	43.3	44.7
Down 20 cm stairs		46.3	0.4	45.4	47.1	

Before: flatfoot before treatment; After: flatfoot after treatment; Normal: normal feet

flatfoot, the stability of the arch is so weak that it is more easily deformed when walking down stairs. That is to say, walking down stairs is harmful to the arch of the foot. This is important because people generally choose to take an elevator when traveling to higher floors in a building, but when traveling to lower floors, they generally prefer to take the stairs rather than wait for an elevator, as long as the number of floors is not too high.

Finally, insufficient attention has been paid to the conservative treatment of flexible flatfoot, and whether adults with flexible flatfoot need to be treated has always been controversial^{2, 10}. The present study shows that flatfeet and even normal feet are influenced by walking down stairs. Furthermore, none of the participants experienced discomfort during the treatment, and the therapeutic effects were apparent. Therefore, use of orthotic insoles could be recommended for treatment of flexible flatfoot to prevent further development. However, further study should be conducted to estimate the effects of orthotics on other plantar pressure variables in the future.

Conflict of interest

The authors declare that there have no conflicts of interest.

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