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Original Article

The Effects of Foot Orthosis on the Gait Ability of College Students in Their 20s with Flat Feet

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Abstract. [Purpose] This study examined the effects of foot orthosis on the gait ability of college students in their 20s with flat feet. [Subjects and Methods] The subjects were 20 college students who had been diagnosed with flat feet. The subjects' step time, step length, stride time, stride length, and gait velocity were measured using the VICON Motion System (Vicon, Oxford, UK) prior to and while wearing foot orthoses. The resulting data were analyzed using SPSS v. 12.0. [Results] The subject's step time and stride time significantly decreased for both feet after they began using foot orthosis, and stride length and gait velocity significantly increased in both feet orthosis; however, step length did not significantly increase on either side. [Conclusions] College students with flat feet saw an improvement in elements of their gait while using the foot orthosis. The results of this study verified that students with flat feet might walk more efficiently if they received active gait training via long-term use of foot orthosis.
Key words: Flat feet, VICON, Gait performance

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INTRODUCTION

Gait, one of the most basic elements of human activity, involving the rhythmic moving of the bilateral lower extremities through alternation of the swing phase and the stance phase. The feet in particular are essential for supporting the body and maintaining balance[1)]. They perform an important function in the lower kinetic chain, distributing and dispersing the load resulting from exercise during the stance phase. A bad gait habit leads to imbalance between the feet. Having flat feet, which is the most representative type of foot deformity, causes changes in the skeletal structure, ligaments, and muscles, typically triggering pes planus or planovalgus. Anatomical change in the tarsal bones transforms, their motion mechanism and trigger fatigue, degenerative arthritis, and secondary deformity of the front at the feet. Walking or standing up may be accompanied by spontaneous pain and fatigue. Sports and excessive activity may impair the function of the feet and continuously aggravate such impairments[2)]. Excessive pronation in the gait of those with flat feet delivers load to the tibia causing pain in the tibias and knees, and damage to the lower limb[3)].

Functional foot orthosis intended to resolve foot malformation has been used to treat many biodynamic problems. Pratt[4)] observed that functional foot orthosis prevented or corrected foot malformation, formed a sufficient base of support, promoted standing or walking exercise, and improved gait efficiency. Foot orthoses are also crucial aids for treating dysfunction of the lower extremities related to abnormal mechanisms and alignment[5)]. Foot orthoses are used to prevent excessive pronation or supination, the most basic causes of lower limb injuries, and to reduce the vertical impact force. Many studies have aimed at finding methods to corrects excessive pronation and supination, and reduce the ground reaction force. Cornwall and McPoil[6)], for example, noted that foot orthosis decreased not only pronation but also the medial rotation of the tibia. Nigg et al.[7)] asserted that appropriate insoles and orthosis reduced muscle activity, gave a feeling of comfort, increased the user's ability to exercise, and resulted in few complications[8)].

Although diverse studies on gait function employing orthoses have reported improvements in terms of exercise performance research on gait in relation to orthosis remains insufficient. Accordingly, this study set out to examine the effects of functional foot orthosis on the gait ability of college students in their 20s with flat feet using the VICON Motion System.

SUBJECTS AND METHODS

Subjects

This study was conducted from April 20 to April 30, 2014, with 20 undergraduates of K University, Chungcheongnam-do, as subjects. The subjects had no history of musculoskeletal system disease and were diagnosed with flat feet, a calcaenal pitch angle that was less than 15° in radiological measurements. After the subjects were selected,

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Table 1. General characteristics of the subjects

	Subjects (n=20)
Sex (M/F)	12 / 8
Age (yrs)	23.4 ± 2.4
Height (cm)	162.3 ± 7.7
Weight (kg)	59.3 ± 12.1
Calcaneal pitch angle (°)	14.1 ± 0.3

Values are mean ± SD

Table 2. A comparison of the gait measures between before while wearing foot orthosis

		Before	Wearing
Step time (sec)	R	0.6 ± 0.0	0.5 ± 0.0*
	L	0.6 ± 0.0	0.5 ± 0.0*
Step length (m)	R	0.6 ± 0.0	0.7 ± 0.0
	L	0.6 ± 0.0	0.7 ± 0.0
Stride time (sec)	R	1.2 ± 0.0	1.1 ± 0.0*
	L	1.2 ± 0.0	1.1 ± 0.0*
Stride length (m)	R	1.3 ± 0.0	1.4 ± 0.0*
	L	1.2 ± 0.0	1.3 ± 0.0*
Gait velocity (m/s)		1.1 ± 0.2	1.2 ± 0.2*

Values are mean ± SD, R: Right side, L: Left side, *Significant difference compared with before orthosis <0.05

they received an explanation of the study and gave their consent to participation. The study was approved by the Clinical Trial Review Committee of Korea Nazarene University, after reviewing it according to the ethical principles of the Declaration of Helsinki. The general characteristics of the subjects who took part in the study are summarized in Table 1.

Methods

The subjects wore foot orthoses made of thermoplastic which were customized to fit their foot size. The orthosis comprised high-density pads with high-elastic rebound cupsoles for plantar support and low-elasticity pads and ethylene vinyl acetate to absorb the impact of the heel. In essence, the insoles were designed to position the heel bones vertical to the ground and to maintain the subtalar joint in a neutral position, thereby preventing pronation, excessive movement of the whole foot, and redistributing the weight load across the foot. The insoles were manufactured by Alfoots (Korea) using casts of the subjects' feet. An experimenter measured and evaluated the subjects' feet, cast both feet using Pedilen foam, prepared positive plaster models, marked sensitive areas and the areas of greatest pressure, and modeled each foot using thermoplastics. The orthoses were polished to shape them and adjust their alignment. Adding a cover completed the production of the foot orthosis[9, 10].

This study used six MX-F40 cameras (VICON, Oxford, UK), two OR6-7 force plates (AMTI, USA), and Nexus software. Nexus software calculates the segment values of each body part and the location of each data item by reconstructing three-dimensional images from the two-dimensional images obtained by recording the optical markers with each camera. The cameras can shoot up to 2,000 fps. Force plates measure the ground reaction force of both feet during gait. The Ultranet system was employed to synchronize the kinetic data obtained from the cameras and the kinematic data obtained from the force plates into the same frame.

The gait variables of step time, step length, stride time, stride length, and gait velocity were measured using the VICON Motion System (Vicon, Oxford, UK) prior to and while wearing the orthoses to measure the gait ability of the subjects. The validity and reliability of the system have been verified in previous studies.

All of the subjects walked three times at self-determined speeds and the average values of the three measurements were adopted for the analysis. Data analysis was carried out using SPSS v. 12.0. The paired t-test was performed to compare the pre- and post-training differences. The statistical significance was accepted for values of $p < 0.05$.

RESULTS

The subjects's step and stride times of both feet significantly decreased when they wore the foot orthoses ($p < 0.05$). Their stride length and gait velocity also significantly increased in both feet orthosis ($p < 0.05$), however, their step length did not significantly increase on either side ($p > 0.05$) (Table 2).

DISCUSSION

Functional foot orthoses fill the space beneath the foot arch preventing the collapse of the arch during dynamic movements[11]. They also control the motion of the ankle joints, decrease plantar friction[12], evenly distribute weight over the soles[13], and reduce pressure on contact areas[14]. Consequently, foot orthoses are judged to improve the gait of those with flat feet. This study set out to examined changes in the gait ability of college students in their 20s with flat feet while wearing functional foot orthoses. The subjects' step time and stride time significantly decreased and their stride length and gait velocity significantly increased when the wore foot orthoses. However, their step length did not significantly increase on either side. When the subjects with flat feet wore the functional foot orthoses that were designed for their exact foot shape, their gait was improved because body's center of gravity—which had leaned excessively toward the inside of the feet—became similar to that of people with normal foot arches.

In patients with lower limb injuries, functional foot orthoses have been shown to distribute the body weight evenly over the plantar surface and support the arches, enabling the effective absorption of impacts, reducing the ground reaction force, and restricting the movement of painful or unstable joints; the orthoses also dispersed and reduced the pressure on painful areas, alleviating discomfort[15]. In quadriplegic patients, functional foot orthoses evenly disperse pressure on the feet by compensating for functions that the feet could not perform or performed inadequately during each phase of gait[16]. Wu[17] reported that foot orthosis could be used to align and support areas of the foot, to prevent and correct foot malformation, and to enhance foot functions. Of particular relevance to the present study, functional foot orthosis can change the gait mechanism of those with flat feet, affecting other lower limb joints[18]. Foot orthoses have been reports to have a notable effect in treating lower extremity diseases[19]. The results of the present study regarding improvements in the lower extremities and feet due to foot orthosis, are in agreement with those previously published in the literature.

The limitations of this study include the small number of subjects, the restricted age range (between 20 and 30 years), and the lack of diversity in the cohort. Based on the present study's results, however, rehabilitation using functional foot orthosis should be actively applied and studies should be conducted on the movements of the ankle joints in linkage with the subtalar joints.

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