



Original Article

Impact of wearing a functional foot orthotic on the ankle joint angle of frontal surface of young adults with flatfoot

KYOCHUL SEO, PhD¹⁾, SEUNGHWAN PARK, PhD^{2)*}, KWANGYONG PARK, MS³⁾

¹⁾ Department of Physical Therapy, Korea Nazarene University, Republic of Korea

²⁾ Department of Medical Engineering, Eulji University: 553 Sansungdaro Sujung-gu, Sungnam city, Gyeonggi-do 461-713, Republic of Korea

³⁾ Department of Rehabilitation Technology, Korea Nazarene University, Republic of Korea

Abstract. [Purpose] This study investigated the effects of proprietary foot orthotics in young adults with flatfoot to determine changes in the ankle joint angle in the coronal plane during the midstance phase. [Subjects and Methods] The subjects were 15 college students diagnosed with flatfoot. Changes in the ankle joint angle in the coronal plane in the midstance phase were measured using the Vicon Motion System before and after use of the orthotic. The data were analyzed using Statistical Package for the Social Sciences Win 16.0. [Results] The subjects showed significant increases in left and right ankle joint angles in the coronal plane during the midstance phase of the gait cycle after use of the orthotics. However, the difference between the left and right ankle joint angles showed no significant change, even though the difference increased after use of the orthotics. [Conclusion] Young adults with flatfoot showed increased ankle joint angles after use of the orthotics. This suggests that orthotic footwear can shape the plantar arch and affect the ankle joint, and that constant use of orthotics would cause a dynamic change in normal walking.

Key words: Flat-foot, Vicon, Gait cycle

(This article was submitted Nov. 21, 2016, and was accepted Feb. 2, 2017)

INTRODUCTION

Walking is essential for daily life, and feet play an important role in supporting the body and maintaining balance during walking¹⁾. Flatfooted walking induces excessive foot pronation, which transfers the weight load to the tibia, causing pain in the tibia and knee. This can result in damage to the lower limb²⁾. Flatfoot is characterized by a medial longitudinal arch that is lowered in a chronic or abnormal way, resulting in excessive stretching of the plantar fascia, spring ligament, and tibialis posterior tendon³⁾. The ability to receive and disperse weight decreases with abnormality of the sole structure, and excessive compensation by the outer muscles causes foot imbalance⁴⁾.

Previous research on functional foot orthotics (FFOs) has produced many results for the treatment of congenital and acquired flatfoot. Pratt⁵⁾ examined the prevention or correction of foot deformity, formation of sufficient supporting ground, promotion of standing or walking exercise, and improvement of walking efficiency. Feet play an important role in the lower kinetic chain; they distribute the weight load generated during exercise and disperse it in the stance period during walking. Song⁶⁾ reported that orthotics decrease both pronation and internal rotation of the tibia. And proper insoles and orthotics could reduce muscle activity, provide comfort, and increase exercise ability^{7, 8)}. An FFO supports a balanced weight distribution in the plantar area and arch, and aids in efficient shock absorption, including the ground reaction generated during walking or running, thus reducing pain and unstable joint motion⁹⁾.

*Corresponding author. SeungHwan Park (E-mail: pasuhwa@eulji.ac.kr)

©2017 The Society of Physical Therapy Science. Published by IPEC Inc.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: <http://creativecommons.org/licenses/by-nc-nd/4.0/>).

As noted above, research and analysis have been conducted with use of FFOs in walking, and on the resulting performance and effects on kinematic functions. However, research studies on changes in ankle joint motion in the coronal plane during the gait cycle through the body center have not been reported. In this study, the effects of use of FFOs on changes in the ankle angle in the coronal plane during the midstance phase of the gait cycle in young adults with flatfoot were examined using the Vicon Motion System (Vicon, Oxford, UK).

SUBJECTS AND METHODS

This study was conducted from January 1 to 31, 2016, and included 15 college students enrolled in University K, in Cheonan City, Korea. The study participants had no musculoskeletal disease, and were diagnosed with flatfoot, with a calcaneal pitch angle less than 5° on radiograph. The subjects fully understood the study, and provided written, informed consent. This study was approved by the Clinical Test Screening Committee at Korea Nazarene University, and was reviewed according to the Declaration of Helsinki. The general characteristics of the research subjects who participated in this study are summarized in Table 1.

The FFOs used by the subjects in this study were customized for each individual's foot shape and created with thermo-plastic materials. A high-density resistance elastic pad, cup sole for the plantar arch, low-elasticity pad for shock absorption in the heel, and ethylene-vinyl acetate (EVA) were used to create the FFOs. When designing the foot orthotic for a subject, the researcher positioned the heel bone vertical to the ground and allowed the subtalar joint to maintain its natural position. While preventing pronation and excessive movement of the feet, measurements were taken and an evaluation was performed with weight loaded under the realigned condition of the foot. Next, the orthotic was cast, and Al foots Inc. in Korea (Short leg brevis, Daeho, Korea) was commissioned for its fabrication. Specifically, the experimenter measured and evaluated the subjects' feet and molded both foot shapes using Pedilen foam. (Short leg brevis, Daeho, Korea) With a prepared positive plaster model, correction was performed (checking pressure points or sensitive parts of the feet), followed by shell production and modeling with thermoplastic. Next, posting and grinding (trimming and alignment adjustment) were performed and the production of the foot orthotic was finalized with a covering material^{10, 11}.

The study equipment consisted of six MX-F40 cameras (Vicon, Hansung, Korea), two OR6-7 force plates (Scan, AMTI, USA), and Nexus software. (Scan, AMTI, USA) Each MX camera transforms two-dimensional images obtained from optical markers into three-dimensional (3D) images, so that in addition to the location data for the markers, measurements for each segment of the body can be obtained. It is capable of measurement up to 2,000 fps. The force plates express the ground reaction force of both feet during walking as vectors. An Ultramet system (Scan, AMTI, USA) synchronized the mechanical motor data from the camera and the kinematic data from the force plate into the same frame^{12, 13}.

To compute the ankle joint angle, a Plug-in Gait model (Scan, AMTI, USA), based on the Newington-Helen Hayes gait model, was used. This was measured with a 3D motion capture device from the Vicon Motion System. The local coordinate system of each segment was created using the 3D spatial coordinates of each measured marker point, and a Euler algorithm was derived. Each gait cycle was differentiated using the heel strike as a standard, and one gait cycle of walking from each subject was extracted for time normalization¹².

In this experiment, only the results of the midstance were derived, where the body weight has the greatest effect during the gait cycle. To measure the changes in ankle joint angle in this study, the subjects walked on a prefabricated walkway, and their gait was analyzed with a high-performance 3D camera using the Vicon Motion System before and after use of the customized FFOs. Experiments were performed at the front of the subject's feet and the subject maintained a straight posture with both feet spreading as shoulder width. Markers on the proximal part of 2nd toe heads and the frontal part of navicular bones on both sides were used to measure the ankle angle of the midstance during a gait cycle. The differences between the left and right ankle joint angles were calculated by quantifying the dynamic changes. All subjects repeated the preliminary motions three times to adjust to the experiment. The mean data of three trials were used in the statistical analysis. The Statistical Package for the Social Sciences Windows 16.0 was used for the data analysis. Changes in the ankle joint angle after use of FFOs were analyzed with a paired comparison t-test, and the individual left and right changes in the ankle joint angles were analyzed with an independent comparison t-test. The statistical significance level was set at $p < 0.05$.

RESULTS

After use of the orthotics by the experimental group, significant increases in the left and right ankle joint angles were observed in the midstance of the gait cycle ($p < 0.05$). However, the difference between the left and right ankle joint angles showed no significant change ($p > 0.05$) (Table 2).

DISCUSSION

This study investigated changes in the ankle joint angle during the midstance phase of the gait cycle after the use of proprietary foot orthotics by 15 college students diagnosed with flatfoot. The flatfoot was due to the change in the position of the navicular bone caused by various congenital abnormalities in the ligaments and joints. An FFO can reduce the height

Table 1. General characteristics of the participants

	Subjects (n=15)
Gender (M/F)	9 / 6
Age (years)	22.1 ± 3.3
Height (cm)	163.3 ± 4.1
Weight (kg)	62.3 ± 3.1
Calcaneal pitch angle (°)	2.8 ± 1.1

Values are the mean ± standard deviation (SD).

Table 2. Ankle joint angle before and after use of foot orthotics

	Midstance (°)	
	Before	After
Right	3.5 ± 0.3	10.2 ± 0.8*
Left	2.3 ± 0.5	11.5 ± 0.6*

Values are Mean ± SD, *Significant difference from the pre-test value, p<0.05

change of the foot arch, and prevents its collapse during dynamic movement. One study reported that FFOs conserve energy during walking by reducing fatigue in the foot muscles, which is frequently observed among flatfoot patients¹⁴). Based on this study, FFOs were fitted, and the subjects showed significant increases in the left and right ankle joint angles in the midstance phase after use of the orthotics. This result suggests that the use of proper FFOs by subjects with flatfoot can relieve tension in the sole muscles and fascia exposed to severe stress in the midstance phase of the flatfoot gait. FFO use would maintain the normal plantar arch, reduce eversion of the ankle joint, and move inversion closer to the normal angle. The wearing of the orthosis increased the angle by relaxing the tension of the muscles of the sole and the fascia which were severely stressed than the normal in the middle stance of the flat walking and maintaining the bow shape of the normal sole.

Wu¹⁵) reported that orthotics can be used for foot alignment and support, prevention and correction of foot deformities, and improvement of foot function. Orthotics help to evenly disperse shock on the sole by compensating for functional insufficiencies in the flat foot during each phase of walking¹⁶). If individuals with flatfoot develop disorders of the joints and feet, FFOs can alter the walking mechanism, which consequently affects the other lower limb joints¹⁷). FFOs return abnormally altered joints to their normal anatomy. Therefore, use of FFOs moves the changed foot arch in the sagittal plane of the ankle joint to the normal range. Previous studies reported that the use of proprietary FFOs resulted in near-normal motion in the lower limb and foot joints, similar to the changes observed in the ankle joint angle in this study. However, only 15 young adults participated in this study, limiting the applicability to other age groups. Further research on the use of FFOs based on the findings of this study should investigate 3D motion in the ankle joint.

ACKNOWLEDGEMENT

This research was supported by the Korean Nazarene University Research Grants 2017.

REFERENCES

- 1) Perry J, Burnfield JM, Cabico LM: Gait analysis: normal and pathological function. SLACK Inc., 2010.
- 2) Eng JJ, Pierrynowski MR: Evaluation of soft foot orthotics in the treatment of patellofemoral pain syndrome. *Phys Ther*, 1993, 73: 62–68, discussion 68–70. [[Medline](#)]
- 3) Houglum PA, Bertoti DB: Brunnstrom' Clinical kinesiology, 6th ed. FA Davis, 2012.
- 4) Neumann DA: Kinesiology of the musculoskeletal system, 2nd ed. Elsevier, 2013.
- 5) Pratt DJ: A critical review of the literature on foot orthoses: foundation of rehabilitation. *JAPMA*, 2000, 90: 339–341.
- 6) Song JH: The Kinematic comparative study about effects of foot orthotics. *Korean J Sport Sci*, 2008, 19: 11–21.
- 7) Hannaford DR: Soft orthoses for athletes. *J Am Podiatr Med Assoc*, 1986, 76: 566–569. [[Medline](#)] [[CrossRef](#)]
- 8) Nigg BM, Nurse MA, Stefanyshyn DJ: Shoe inserts and orthotics for sport and physical activities. *Med Sci Sports Exerc*, 1999, 31: S421–S428. [[Medline](#)] [[CrossRef](#)]
- 9) Gross ML, Napoli RC: Treatment of lower extremity injuries with orthotics shoe insert. *Sports Med*, 1993, 15: 66–70. [[CrossRef](#)]
- 10) Takata Y, Matsuoka S, Okumura N, et al.: Standing balance on the ground—the influence of flatfeet and insoles. *J Phys Ther Sci*, 2013, 25: 1519–1521. [[Medline](#)] [[CrossRef](#)]
- 11) Lee Y, Her JG, Choi Y, et al.: Effects of ankle-foot orthosis on lower limb muscle activities and static balance of stroke patients author's names. *J Phys Ther Sci*, 2014, 26: 179–182. [[Medline](#)] [[CrossRef](#)]
- 12) Seo KC, Park KY: The effects of foot orthosis on the gait ability of college students in their 20s with flat feet. *J Phys Ther Sci*, 2014, 26: 1567–1569. [[Medline](#)] [[CrossRef](#)]
- 13) Park K, Seo K: Effects of a functional foot orthosis on the knee angle in the sagittal plane of college students in their 20s with flatfoot. *J Phys Ther Sci*, 2015, 27: 1211–1213. [[Medline](#)] [[CrossRef](#)]
- 14) Franco AH: Pes cavus and pes planus. Analyses and treatment. *Phys Ther*, 1987, 67: 688–694. [[Medline](#)]
- 15) Wu KK: Foot orthoses: principles and clinical applications. Baltimore: Williams & Wilkins, 1990, p 97.
- 16) Hertel J, Sloss BR, Earl JE: Effect of foot orthotics on quadriceps and gluteus medius electromyographic activity during selected exercises. *Arch Phys Med Rehabil*, 2005, 86: 26–30. [[Medline](#)] [[CrossRef](#)]
- 17) Magee DJ: Orthopedic physical assessment, 3rd ed. Philadelphia: WB Saunders, 1998.