

The Effects of Transverse Arch Insole Application on Body Stability in Subject with Flat Foot

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Background The most commonly applied therapeutic intervention is foot orthosis (insole or wedge) for arch support. However, the effect of these varies and remains controversial. Most of the studies were that investigated the muscle activity of insole application, and there was no information on what kind of recovery effect it had functionally.

Purpose The purpose of this study was to investigate the effect of transverse arch insole on lower extremity kinematics in subject with flat feet during one-leg standing.

Study design A cross-sectional study

Methods Fifteen young women and five men participated in this study. Participants performed one leg standing between with and without transverse arch support. During one-leg standing, lower extremity movements (vertical/horizontal displacement of knee/ankle joints) were video-recorded and then analyzed using Kinovea software. A paired *t*-test was used to compare the characteristics between with and without the transverse arch insole.

Results The use of a transverse arch insole significantly decreased the vertical and horizontal displacement of the knee and the vertical displacement of the ankle during one-leg standing in subject with flat foot ($p < 0.05$).

Conclusions Our study investigated the effects of transverse arch support on lower kinematics in subject with flat feet during one leg standing. During one-leg standing, there were significant differences between with and without transverse arch insole in lower extremities kinematics (vertical/horizontal displacement of knee/ankle joints). Therefore, it was confirmed that supporting the transverse arch when treating or managing subjects with flat feet can reduce unnecessary lower extremity movements and increase the stability of the body extremities.

Key words Flat feet; Lower extremity; One leg standing; Stability; Transverse arch insole.

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INTRODUCTION

The foot arch is composed of various bones, muscles and soft tissues of the foot and performs various functions such as weight bearing, shock absorption, and energy control.¹ Foot arches are classified into longitudinal (medial/lateral) and transverse.² A common injury to the foot arch in more than 20% of the population is a flat foot.³ It is characterized by medial rotation and plantar flexion of the talus, eversion

of the calcaneus, collapsed medial arch and abduction of the forefoot and their causes are ligamentous laxity, neurogenic and muscular abnormalities, genetics problems, and collagen disorders.^{4,5}

Flat foot can be classified into flexible flat foot and rigid flat foot. The rigid flat foot maintains the shape of a flat foot regardless of whether or not it supports weight, but in the case of flexible flat foot, the arch of the foot is only supported when weight is supported. It has the characteristic of

collapsing.⁶ Disintegration of the medial longitudinal arch of the foot occurs during weight-bearing standing posture or walking due to these various causes.⁷ Flat foot is not only influences the performance of the foot, but also affects the alignments of the ankle, knee and hip joints. When the foot arch flattened repeatedly causes abnormal alignment and movement in the lower extremities, causing damage to the lower extremity structure and pain.⁸ Therefore, when evaluating problems caused by flat feet, it is important to evaluate not only the problems of the foot itself, but also problems that may occur in functional activity situations. Among the various evaluation methods, the one-leg standing test is a good test to evaluate the effect of flat feet on the movement of lower extremity and because it is a movement that occurs frequently during daily activities.⁹

The most commonly applied therapeutic intervention is foot orthosis (insole or wedge) for arch support. However, the effect of these varies and remains controversial. Most of the studies were studies that investigated the muscle activity of insole application (the applied insole or wedge was designed to support the inner/longitudinal arch of the foot), and there was no information on what kind of recovery effect it had functionally.¹⁰⁻¹² From a different perspective, Venkadesan et al. found that the transverse arch is a very strong and stiff spring lever and provides 40% of foot stiffness.¹³ This function allows energy to be stored in the intrinsic elastic structure of the foot during foot propulsion.¹³ In order to maintain the normal function and arch of the foot, it is important to maintain the normal alignment of the mid-foot, that is, the transverse arch. Therefore, the purpose of this study was to investigate the effect of transverse arch insole on lower extremity kinematics in subject with flat feet during one-leg standing. It was hypothesized that a transverse arch insole would decrease lower extremity kinematics in subject with flat feet during one-leg standing.

METHODS

Participants

Fifteen young women and five men participated in this study (age: 22 ± 3.5 Height: 164 ± 10.1 , Weight: 60.3 ± 8.9). Participants had to have at least 3 of the following characteristics of the foot by criteria of previous studies (Inclusion criteria): (1) medial protrusion of the head of the talus, (2) calcaneus eversion more than 0 degree (3) mid-foot collapse (more than 1 cm navicular drop), (4) forefoot or rear foot abduction (lateral toes more visible than medial toes).¹⁴⁻¹⁵ The exclusion criteria included fracture, dislocation, structural malformation, and severe pain of the lower extremity. All participants gave written informed consent prior to the

experiment. The study was approved by the ethics committee Institutional Review Board of Sangji University (IRB no. 1040782-220104-HR-01-94).

Instrumentation

1) Transverse arch support

Participants performed one leg standing between with and without transverse arch support. It is a transverse arch support (Realine insole sports; Realine co., Ltd., Japan) that can be applied according to the patient's height. And the arch supporter is composed of plastic and compressed foam, and the size is 260-270mm for men and 230-240mm for women, and can be cut to fit your size. Add additional reinforcement to the sole of the insole to support the transverse arch.

2) 2-Dimensional video analysis

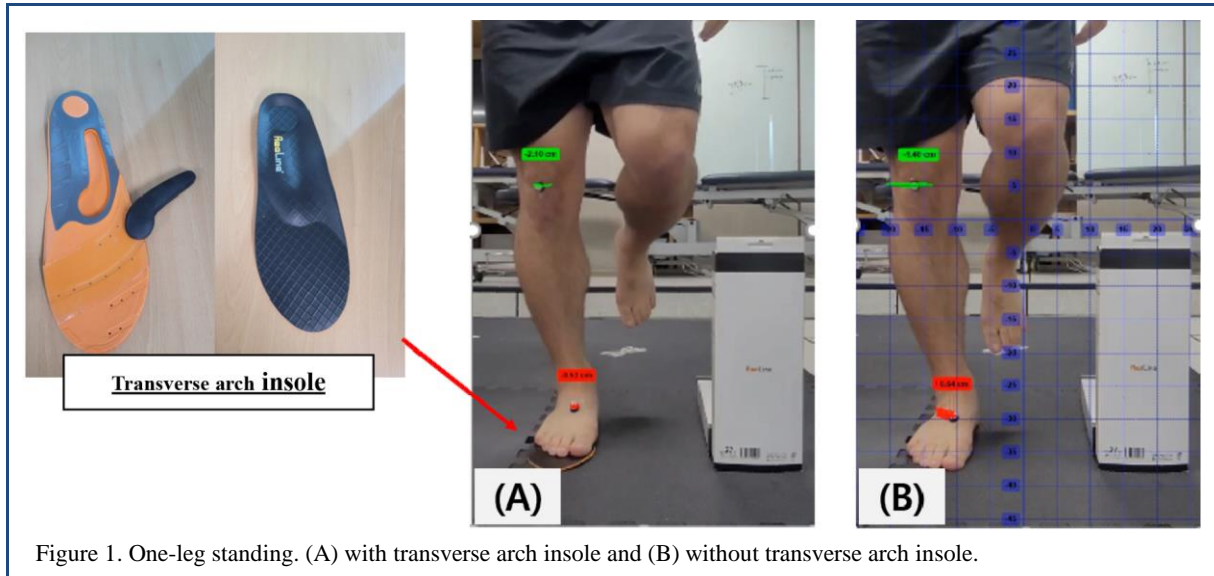
The movements (knee/ankle) of the subjects' lower extremity during one-leg standing were recorded using a Samsung Galaxy S20 Note smartphone (Samsung electronics, South Korea). An adjustable tripod was placed 1 m in front of the participants and placed at the level of the knee joint. Round markers of 1 cm in diameter were attached on the mid-point of the patellar and dorsum of the 2nd metatarsal bone base.

Procedure

The participants were asked to stand with their feet on the transverse arch insole (supporting feet). One leg standing test was conducted in each condition with or without transverse arch application. A participant stands on one leg with the contralateral knee flexion 90° for 5 s. Both hands were positioned parallel to the body. The participants were kept as balanced as possible until there was a signal to stop with the signal to start the experimenter. The experiment was stopped when an unbalanced posture (unsupported feet touched the ground or the torso was tilted excessively) from the starting position. During one-leg standing, lower extremity movements (vertical/horizontal displacement of knee/ankle joints) were video-recorded and then analyzed using Kinovea software. Kinovea[®] is a free 2D motion analysis software that enables the establishment of kinematics parameters. All recorded videos were analyzed with the stable version of Kinovea (v. 0.8.15, Kinovea, Bordeaux, France) (Figure 1).

Statistical analysis

Statistical analyses were performed using the SPSS for Windows (ver. 25.0 software; IBM Co., Armonk, NY, USA).



To verify the normality of data distribution, the Kolmogorov-Smirnov test was used. A paired *t*-test was used to compare the characteristics (lower extremities kinematics; vertical/horizontal displacement of knee/ankle joints) between with and without the transverse arch insole. The level of statistical significance was set at α of 0.05.

RESULTS

The Shapiro-Wilk test showed the normality of the data ($p > 0.05$). Except for vertical displacement in the knee, there were significant differences between with and without transverse arch insole in lower extremities kinematics (vertical/horizontal displacement of knee/ankle joints) ($p > 0.05$). The results of the lower extremities kinematics with and without transverse arch insole are shown in Table 1.

DISCUSSION

The transverse arch of the foot is a stiff spring lever that provides more than forty percent of foot stiffness. This foot stiffness helps the intrinsic elastic structures of the foot to

store energy which is utilized during foot propulsion.¹⁴ For flat foot with collapsed transverse arch, therapeutic intervention is important to maintain normal alignment and support.¹² In addition to therapeutic exercise, it is necessary to verify the effectiveness of the transverse arch insole to maintain the normal arch of the foot.¹⁶⁻¹⁷

The purpose of this study was to investigate the effect of transverse arch insole on lower extremity kinematics in subject with flat feet during one-leg standing. It was found that there was a significant difference in lower extremity kinematics (knee/ankle vertical-horizontal displacement) between with and without the transverse arch insole. Compared with the vertical displacement, there was a large difference in the amount of horizontal displacement. The transverse arch support provided stability to the ankle joint and minimized physical sway that may occur during an unstable one-foot lift. Based on the experimental results, it is thought that the stability of the ankle joint due to the transverse arch support had a great effect on the stability of the knee joint. Flat foot means not only the morphological change of the foot but also the instability of each joint in the body during various physical activities such as lifting one

Table 1. Comparison of the kinematic data with and without transverse arch insole

Variables		With transverse arch insole	Without transverse arch insole	<i>t</i>	<i>p</i>
Horizontal displacement (cm)	Knee	6.2±1.9	3.19±1.16	12.056	<0.001*
	Ankle	3.00±0.50	1.69±0.46	13.183	<0.001*
Vertical displacement (cm)	Knee	0.36±0.14	0.35±0.15	1.497	0.151
	Ankle	2.00±0.50	0.46±0.29	10.577	<0.001*

* $p < 0.05$.

foot, walking, and running. Therefore, there is a need for a therapeutic intervention to maintain the alignment of the foot in a static/dynamic state. Considering the effect of flat feet, it is very important to check the movement of lower extremities that can occur during functional movements such as one-leg standing due to flat feet.

Our study had some limitations. First, it is difficult to generalize our results to all ages. Only young individuals participated. Second, the change in the activity of lower extremity muscle activity according to the transverse arch insole application was not measured. In further studies, research on lower extremity muscle activity with or without insole application is needed. Third, only the vertical-horizontal displacement of the foot/knee was measured. The part related to rotation could not be measured. Future research will require 3-D measurements to measure rotation.

CONCLUSIONS

Our study investigated the effects of transverse arch support on lower kinematics in subject with flat feet during one-leg standing. During one-leg standing, there were significant differences between with and without transverse arch insole in lower extremities kinematics (vertical/horizontal displacement of knee/ankle joints). Therefore, it was confirmed that supporting the transverse arch when treating or managing subjects with flat feet can reduce unnecessary lower extremity movements and increase the stability of the body extremities.

Key Points

Question How does applying a transverse arch insole affect the movement of lower extremity in a patient with flat feet during one-leg standing?

Findings During one-leg standing, there were significant differences between with and without the transverse arch insole in lower extremities kinematics (vertical/horizontal displacement of knee/ankle joints).

Meaning Supporting the transverse arch when treating or managing subjects with flat feet can reduce unnecessary lower extremity movements and increase the stability of the body extremities.

Article information

Conflict of Interest Disclosures: None.

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Ethic Approval: The study was approved by the ethics

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