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# Results of the Use of Navicular Support Foot Orthoses in Children with Flatfeet

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**Abstract**

Various foot orthoses have been studied for their ability to alleviate the symptoms of flatfoot. While many interventions feature medial longitudinal arch support, this study aimed to compare resting calcaneal standing position, talocalcaneal angle, talo-metatarsal angle, and navicular height before and after treatment with navicular support in children with flatfeet. In total, 10 participants (6 males and 4 females; mean age 10.8 ± 1.61 years) wore navicular orthotic support for more than 8 hours a day throughout the 12-month study period. X-ray and physical measurements were carried out before the intervention (baseline) and after 6- and 12-months of treatment. All measurements were performed without orthotics. Analysis showed that the resting calcaneal standing position and navicular height increased, while the talocalcaneal and talo-metatarsal angles decreased, when comparing data at baseline to 6- and 12-months of treatment. In summary, our research findings show that orthotics with navicular support improve the symptoms associated with flatfeet in children when worn for more than 8 hours per day for at least 6-months.

***Keywords:*** *navicular support, flexible pes planus, navicular support, resting calcaneal standing position, talocalcaneal angle, talo-metatarsal angle, navicular height*

## 1. INTRODUCTION

The children's flat foot is a most common concern and has long been considered as a problem and worried to be a potentially disabling. Flat foot is widely accepted that a low medial arch and a valgus heel position. The foot is the first area that is in contact with the ground. It provides balance and support during standing and walking and maintains body stability during walking. Furthermore, the foot is divided into three parts due to its functional characteristics: rearfoot, midfoot, and forefoot. The rearfoot is comprised of the talus and the calcaneus, the midfoot is comprised of the navicular, the cuboid, and 3 cuneiforms, and the forefoot is comprised of the metatarsal bone and the phalanges.

The foot has the medial and lateral longitudinal arch and transverse arch. The foot distributes the weight most biomechanically stably to protect the body, and helps reduce fatigue when a person stands or walks for a long time. The medial longitudinal arch of the foot appears to generate with decreasing subcutaneous fat and malaxation of the ligament as a person grows after birth. It begins to develop around 6 years of age, and the generation is completed around 12 years of age [1].

Flatfoot occurs when there is damage in the plantar calcaneonavicular ligament, plantar fascia, or deltoid ligament, which stabilizes the medial longitudinal arch. This occurs commonly, regardless of age or presence of disease, due to various reasons [2].

The normal findings of flat feet versus children's age estimates that approximately 45% of preschool children, and 15% of older children, average age 10 years, have flat feet. In one study among elementary school students in Korea, it was reported that 18.7%

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had at least one flat foot [3]. The pediatric flat foot is a frequent showing in clinical setting. That was common concern to parents and patients themselves. Also, continues to be debated within clinical professional ranks.

With the help of the medial and lateral longitudinal and transverse arches, the foot distributes weight in a biomechanically stable way to protect the body and help reduce fatigue when standing or walking [4]. At around 6 years of age, the medial longitudinal arch of the foot appears to generate with decreasing subcutaneous fat and malaxation of the ligament until around 12 years of age [5]. Most cases of pediatric flatfoot, called flexible flatfoot, are characterized by a reduced medial longitudinal arch when bearing weight. This can occur if there is immature growth of the medial longitudinal arch, problems with soft tissues, neuromuscular problems, such as cerebral palsy and poliomyelitis, or trauma [6]–[9]. Also, joint hypermobility and increased weight or obesity may increase flat foot prevalence.

Most of the pediatric flatfoot deformities is the flexible flatfoot. Flexible flatfoot has the characteristics of showing reduced medial longitudinal arch with weight bearing and normal medial longitudinal arch without weight bearing. Few flexible flat foot have been found to be symptomatic. The navicular, which is a structure that supports the medial longitudinal arch, descends and protrudes medially in the case of a severe flatfoot. Foot orthoses provide a treatment option for people with flatfeet. These plastic braces control the musculoskeletal and joint movement to enhance the function of the foot, namely, they maintain the stability of the joint by inhibiting the ground reaction force which induces abnormal skeletal motion during the stance phase of gait and force the medial and lateral post to correct the flatfoot, stabilizing the heel [10] . The Blake inverted foot orthosis, which is used for flatfeet in children, is structured to support the longitudinal arch. The medially protruding navicular can be somewhat improved as the resting calcaneal stance position (RCSP) is corrected. It has been reported that the cause of the navicular drop is related to the tilt of the subtalar articulation and the medial longitudinal arch when wearing the orthosis [11]. Furthermore, it has been shown that the navicular is at the peak of the medial longitudinal arch and thus the curvature of the medial longitudinal arch is determined by the angle between the axis of the metatarsal bone and the axis of the calcaneus as well as the height of the navicular from the ground, thereby necessitating the correction of the navicular [12].

Various foot orthoses have been studied for their ability to alleviate the symptoms of flatfoot. Most of the studies have been focused on the medial longitudinal arch support, rather than the Blake inverted foot orthosis. Among research focused on the Blake foot orthoses, analysis of the effect of navicular correction is lacking. Therefore, the purpose of this study was to compare the differences in RCSP, talocalcaneal angle, talo-metatarsal angle, and navicular drop before and after children with symptoms of flatfeet wore navicular support orthoses.

## 2. MATERIALS AND METHODS

### 2.1. RESEARCH DESIGN

This was designed quasi-experimental study. A one-group pretest-posttest design was used in this study. RCSP, talocalcaneal angle, talo-metatarsal angle, and navicular drop were tested before this study. And after 6month, 12month, major variables were tested under wore navicular support orthoses in children with symptoms of flatfeet.

### 2.2. RESEARCH PARTICIPANTS

This study included 10 elementary school children who were diagnosed with flexible flatfoot with no symptomatic state. In their both feet, showed a navicular drop when examined by the department of rehabilitation specialist from the Foot Clinic of the Chungnam National University Hospital. Left and right feet were both measured by the department rehabilitation expert technician for a total both of 20 feet.

The selection criteria for the research subjects were:

children with severe flexible flatfeet and simultaneous navicular drop; children without additional other orthopedic prescriptions other than the navicular support for the foot orthosis; flexible flatfeet without any other treatment experience after being diagnosed with flexible flatfoot treatment, and; children who could wear the foot orthoses for 8 hours or more per day.

The study exclusion criteria were:

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children with rheumatoid, fracture, or spinal tumors; a history of orthopedic surgery; presence of chronic pain disorders or neuromuscular pressure; major circulatory system, respiratory, or neurological disease; heart disease; cognitive deficiency; infection, or; children who were being treated by a different institution. All potential participants heard an explanation about the purpose and the procedures of the study before enrollment and voluntarily signed the research consent form.

## 2.3. MATERIALS

Among children diagnosed with flatfoot, study participants who had flexible flatfeet along with a navicular drop were prescribed navicular support orthoses by the department of rehabilitation specialist (Figure 1).

The diagnosis and prescription were performed by a rehabilitation specialist (medical doctor). The production of the orthosis was done after making a negative plaster model using a plaster bandage and produced by an experienced technician and with a technical assistant (Figure 2). To support the descended navicular, the shell of the existing Blake inverted foot orthosis was flange-extended to the navicular area and a pad was used to minimize discomfort due to the pressure from the flange. With the application of these flanges, the supporting surface became wider to distribute pressure. To accurately place the flange on the navicular area, the location and the height were matched by marking the navicular area during the modeling stage so it would appear on the positive model. During the study, the participants wore the navicular support orthoses for 8 hours or more per day. Static foot assessment is commonly performed in clinical practice to classify foot type for prescribing therapeutic interventions. RCSP measurements and X-rays were taken without the foot orthoses. To accurately measure the medial and longitudinal arch, which measures the tilt of the calcaneus before wearing the foot orthosis, lateral X-rays were taken in the standing position. Using the X-ray image, the talocalcaneal and talo-metatarsal angles and navicular height were measured. The measurements were taken before wearing the foot orthosis (baseline), and at 6-and 12-months after starting the orthosis intervention. Age, gender, height and weight were surveyed before static foot assessment in the foot clinic of the Chungnam National University Hospital.

Fig. 1. Navicular support orthoses


Fig. 2. Producing of foot orthosis

During the study, the participants wore the navicular support orthoses for 8 hours or more per day. RCSP measurements and X-rays were taken without the foot orthoses To accurately measure the medial longitudinal arch, which measures the tilt of the calcaneus before wearing the foot orthosis, lateral X-rays were taken in the standing position. Using the X-ray image, the talocalcaneal and talo-metatarsal angles and navicular height were measured. The measurements were taken before wearing the foot orthosis (baseline), and at 6- and 12-months after starting the orthosis intervention.

## 2.4. MEASUREMENT OUTCOME VARIABLES

Measurement of height and weight. An automatic height/weight measurement system (BSM 330, Biospace, Korea) was used to measure the height and weight of the participants at baseline.

Resting calcaneal standing position. For RCSP, a line was drawn to vertically divide the calcaneus in half as the patient was in the prone position without bearing weight on the foot. Next, the angle between the line and the ground in the calcaneal standing position while bearing weight was measured. The measurements were taken before wearing the foot orthosis (baseline), and at 6- and 12-months (Figure 3).

Fig. 3. Method to measure RCSP

Talo calcaneal angle. The angle between the lines that vertically divide the talus and calcaneus in half was measured on a lateral X-ray image to obtain the talocalcaneal angle. The measurements were taken before wearing the foot orthosis (baseline), and at 6- and 12-months (Figure 4).

Fig. 4 Method to measure the talocalcaneal angle

Talo metatarsal angle. The angle between the longitudinal axis of the talus and the longitudinal axis of the first metatarsal bone was measured on a lateral X-ray image to obtain the talo metatarsal angle. The measurements were taken before wearing the foot orthosis (baseline), and at 6- and 12-months (Figure 5).

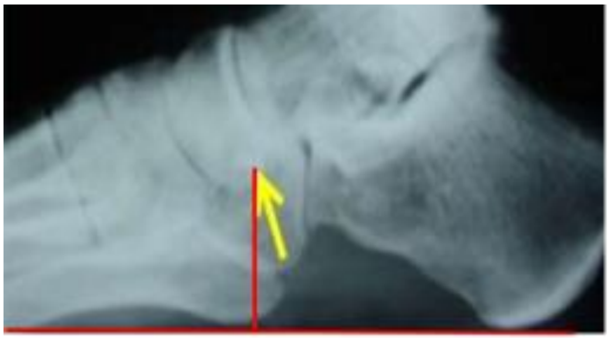

Fig. 5. Method to measure talo-metatarsal angle

Navicular height. The vertical height from the center of the navicular to the ground was measured on the lateral X-ray image to obtain the navicular height (Figure 6).

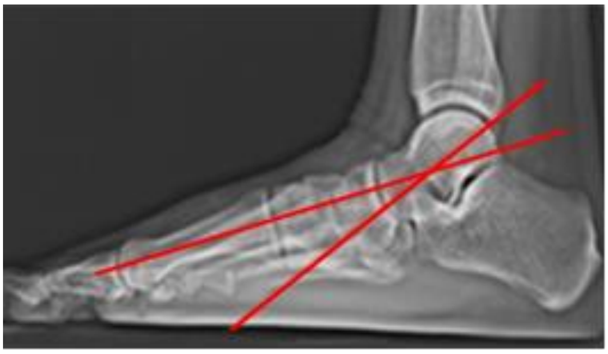

Fig. 6. Method to measure navicular height

## 2.5. ETHICAL CONSIDERATION

The study protocol was approved by the foot-clinic of the Chungnam National University Hospital. Prior to data collection, we informed the participants and their parents of the purpose, method, and anticipated effects of the study and participants' rights to withdraw from the study at any time. Written informed consent was obtained from those who voluntarily expressed willingness to participate in the study.

## 2.6. DATA COLLECTION PROCEDURE

The survey was conducted after obtaining our institution's approval. Among patients who visited

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the department of rehabilitation foot-clinic at university hospital with suspected flat foot, those diagnosed with pediatric flatfoot based on screening by rehabilitation specialist were surveyed at the foot clinic. The RCSP, talocalcaneal angle, talo-metatarsal angle, and navicular height for the assessment of flat foot was performed by an experienced technician and gender, age, height and body weight were obtained from the medical records. The survey and explanation took 30-40 minutes per participant. The researcher provided additional explanations when participants needed clarification and had difficulty responding to the procedure to minimize misunderstand.

## 2.6. STATISTICAL ANALYSIS

This study described the sample by calculating the frequencies, mean ± standard deviation and percentages of participants' general characteristics. To analyze the differences before and after the we calculated means and standard deviations for the RCSP, talo calcaneal angle, talo metatarsal angle and navicular height, analyzed their differences using the paired t-test. Authors tested the normality of the data at pretest and posttest using both the Kolmogorove Smirnov and Shapiroe-Wilk tests for the entire sample and for each age group and found that the normality was secured (i.e., both tests were nonsignificant for an alpha of .05). The RCSP and x-ray data were compared at each timepoint. To test the differences, repeated-measures ANOVA was performed. .If there were statistical differences, a Bonferroni post-hoc test was performed (with $\alpha$ = .05/3 = .017). All statistical significance levels were set to $\alpha$=.05. All data were analyzed using the statistical software program SPSS v. 18.0 for Windows (IBM Corp., Armonk, NY, USA).

## 3. RESULTS

### 3.1. DEMOGRAPHIC CHARACTERISTICS

The mean age of our participants was 10.8±1.61 years and there were 6 (60%) men and 4 (40%) women. Mean height was 148.6 ± 2.61 cm. Mean body weight was36.9 ± 2.23. The general characteristics of the research subjects who participated in this study are shown in Table I.

Table I. General Characteristics of The Research Subjects (N=10)

| | Mean ± SD |
|---|---|
| Gender | Male 6, Female, 4 |
| Age (Years) | 10.8 ± 1.61 |
| Height (cm) | 148.6 ± 2.61 |
| Body weight (kg) | 36.9 ± 2.23 |

SD, Standard Deviation

### 3.2. EFFECTS OF THE FOOT ORTHOSIS

Changes in the RCSP, talocalcaneal angle, talo-metatarsal angle, and navicular height after 12-months of wearing the orthoses are shown in Table II. The results of the post-hoc analysis showed that RCSP significantly decreased from –8.70° before wearing the orthoses to –6.30° at 6-month and -4.85° at 12- month follow-up (p<.001). The talocalcaneal angle significantly decreased from 55.55° before wearing the orthoses to 52.85° at 6-month and 48.40° at 12-month follow-up (p<.001). Furthermore, the talo-metatarsal angle significantly decreased from 19.95° before treatment to 17.35° at 6-month and 14.90° at 12-month follow-up (p<.001). The Navicular height significantly increased from 2.185 cm before treatment to 2.380 cm at the 6-month and 2.585 cm at the 12-month follow-up (p<.001).

Table II. Mean Differences in the Variable by Time

| | Before wearing the foot orthosis Mean ± SD | 6 months after wearing the foot orthosis Mean ± SD | 12 months after wearing the foot orthosis Mean ± SD | *p* |
|---|---|---|---|---|
| Difference in RCSP | -8.7± 1.45 | -6.3± 1.02 | -4.85± 0.57 | <.001*+ |
| Difference in talo calcaneal angle | 55.55± 7.14 | 52.85± 11.4 | 48.4± 6.33 | <.001*+ |
| Difference in talo metatarsal angle | 19.95± 3.16 | 17.35± 5.430 | 14.90± 4.82 | <.001*+ |
| Difference in navicular height | 2.185± 0.54 | 2.38± 0.68 | 2.585± 0.97 | <.001*+ |

*$p$ <.001 Difference between before and 6-months after wearing the foot orthosis, +$p$ <.001 Difference

between before and 12-months after wearing the foot orthosis
RCSP, resting calcaneal stance position. SD, Standard Deviation

## 4. DISCUSSION

The purpose of this study was to compare clinical outcomes before and after wearing the Blake inverted foot orthosis, which adds navicular support to individuals with flatfeet, to examine the effects of treatment in children. When the navicular support foot orthosis was worn for 8 hours or more per day, the RCSP, talocalcaneal angle, talo-metatarsal angle, and navicular height all significantly increased at the 6-month and 12-month follow-up. This indicates that navicular support adjusts the ligaments and muscles that comprise the medial longitudinal arch to correct the flatfoot and improve navicular drop.

Few studies that associate the severity of flatfoot with treatment guidelines and the standards of the studies vary. However, Root and colleagues considered the inversion of RCSP to the range of 4° to 6° as normal [13]. In contrast, Le Lievere reported that an inversion greater than 5° required treatment, although the study was in adults [14]. In the present study, inversion of RCSP greater than 4° was defined as a flatfoot that required treatment according to Pfeiffer et al. and by the developer of the foot orthosis [15]. However, many researchers support the treatment of flatfeet with the appropriate use of foot orthoses. Roye and colleagues posit that pediatric cases of flatfeet need treatment that supports the medial longitudinal arch instead of surgery [16]. Moreover, Kulcu and colleagues reported that while flatfeet do not affect the gait type of the patients, the radiological measurements after wearing the foot orthoses significantly improved [17].

Our study results of putting navicular support foot orthosis on the 20 feet of 10 children diagnosed with flexible flatfoot showed that RCSP, talo calcaneal angle, and talo metatarsal angle all significantly decreased after 6 months of wearing the foot orthosis to 2.40°, 2.70°, and 2.60°, respectively, compared to before wearing the foot orthosis. Compared to before wearing the foot orthosis, these measurements significant decreased to 3.85°, 7.15°, and 5.05°, respectively, after 12 months of wearing the foot orthosis. The decreases in RCSP, talocalcaneal angle, and talo-metatarsal angle continued throughout the study period, which points to the importance of prolonged treatment. Furthermore, the navicular height also continued to increase throughout the follow-up period. This confirms findings by Kim et al., that evaluated navicular support orthoses in children with similar results [18]. Furthermore, compared to the results of a study by Yoon and colleagues that reported an improvement of RCSP by 2° in participant using Blake inverted foot orthoses without navicular support, the improvements reported in the present study tended to be larger [19].

Compared to a study by Lee and collages, who observed the navicular height using radiology 3-months after applying a medial arch support intervention for children with cerebral palsy and reported a 0.46 cm increase, the results of this study were somewhat smaller. However, the results of the study by Lee et al. included children with cerebral palsy and measurements were taken while the participants were wearing shoes. Thus, the results are difficult to compare to the present study, in which the subjects were children with flatfeet and the measurements were made without shoes or foot orthosis [20]. In their study on the clinical measures of lower extremity alignment, Kim and colleagues found an interaction between navicular drop, quadriceps angle, and hip internal rotation angle [21]. In addition, Kim found that increasing comfort with wearing custom-made foot orthoses in a group with excessive-pronation reduced the range of navicular drop and affected the muscle, thus showing the importance of treating the navicular drop [22]. Roth and colleagues took x-rays of children after undergoing surgeries to treat flexible flatfoot and measured the talonavicular angle to compare to pre-surgery data and found that there were differences of about 1.5° compared to the mean talonavicular angle of a normal foot [23]. Even though the angle was not within the normal range, there was no further treatment. Thus, there are advantages to continuously wearing the foot orthosis with navicular support, as was the case in this study, until the desired results are achieved.

There are limitations of this study to consider. First, the study was not designed to make comparisons to other foot orthoses, such as the conventional foot orthoses and there was not a comparison to standard values for the normal ranges of RCSP, talocalcaneal angle, talo-metatarsal angle, and navicular height since the data for Korean children is unavailable. In addition, there was a relatively small sample size so the results cannot be generalized to the larger population. Next, some participants needed minor modifications to the orthosis because of discomfort but all issues were resolved after a period of adjustment.

This study was conducted with a one-group pretest-posttest design without a control group because of difficulties in participant recruitment. This limitation must be considered while interpreting the results of this study. In future studies long-term comparative research using the navicular support foot orthosis and the conventional Blake inverted foot orthosis is needed with a larger number of participants to confirm the preliminary results of this study.

## CONFLICT OF INTEREST

The authors declare there are no financial or other actual or potential conflicts of interest. This paper was written in our own time, no funding was provided and no financial incentives/rewards will be received.

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