Observational Study

Medicine®

OPEN

Analysis of factors influencing improvement of idiopathic flatfoot

Byung-Joon Shin, MD, PhD[a], Kyoung Min Lee, MD, PhD[b], Chin Youb Chung, MD, PhD[c], Ki Hyuk Sung, MD, PhD[b], Dong-il Chun, MD, PhD[a], Chang Hwa Hong, MD, PhD[d], Jun Bum Kim, MD, PhD[d], Sai-Won Kwon, MD, PhD[d], Woo Jong Kim, MD, PhD[d], Min Gon Song, MD[d], Sung Joon Yoon, MD[d], Ki Jin Jung, MD, PhD[d,*]

Abstract

Idiopathic flatfoot is common in infants and children, and patients with this condition are frequently referred to pediatric orthopedic clinics. Flatfoot is a physiologic process, and that the arch of the foot elevates spontaneously in most children during the first decade of life. To achieve a consensus as the rate of spontaneous improvement of flatfoot, the present study aimed to estimate the rate of spontaneous improvement of flatfoot and to analyze correlating factors.

We reviewed the records of patients examined between May 2013 and May 2019 so as to identify those factors associated with idiopathic flatfoot below 12 years of age. We included patients with who had been followed for >6 months, and those for whom ≥2 (anteroposterior and lateral) weight-bearing bilateral radiographs of the foot had been obtained. The progression rates of the anteroposterior (AP) talo-first metatarsal angle, talonavicular coverage angle, lateral talo-first metatarsal angle, and calcaneal pitch angle were adjusted by multiple factors using a linear mixed model, with sex, body mass index, and Achilles tendon contracture as the fixed effects and age and each subject as the random effects.

We found that 4 of the radiographic measurements improved as patients grew older. The AP talo-first metatarsal angle, talonavicular coverage angle, and the lateral talo-first metatarsal angle decreased, while the calcaneal pitch angle increased. The AP talo-first metatarsal angle ($P < .001$), talonavicular coverage angle ($P < .001$), and lateral talo-first metatarsal angle ($P < .001$) improved significantly; however, the calcaneal pitch angle ($P = .367$) did not show any significant difference. In general, the flatfeet showed an improving trend; after analyzing the factors, no sex difference was observed ($P = .117$), while body mass index ($P < .001$) and Achilles tendon contracture ($P < .001$) showed a negative correlation.

The study demonstrated that children's flatfeet spontaneously improved at the age of 12 years. It would be more beneficial if the clinician shows the predicted appearance of the foot at the completion of growth by calculating the radiographic indices and identifying the correlating factors in addition to explaining that flatfoot may gradually improve. This will prevent unnecessary medical expenses and the psychological adverse effects to the children caused by unnecessary treatment.

Abbreviations: BMI = body mass index, ICCS = intraclass correlation coefficients, LMM = linear mixed model.

Keywords: Achilles tendon contracture, flat foot, obesity, radiologic evaluation

Editor: Fatima Naumeri.

B-JS and KML contributed equally to this study.

This research was supported by the Bio & Medical Technology Development Program of the National Research Foundation (NRF) funded by the Ministry of Science & ICT (2021M3E5D1A0201517321).

No benefits in any form have been received or will be received by the authors from commercial parties related directly or indirectly to this article.

The authors have no potential conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] Department of Orthopedic Surgery, Soon Chun Hyang University Seoul Hospital, Seoul, South Korea, [b] Department of Orthopedic Surgery, Seoul National University Bundang Hospital, Seoul, South Korea, [c] Department of Orthopedic Surgery, Bumin Hospital, Seoul, South Korea, [d] Department of Orthopedic Surgery, Soon Chun Hyang University Cheonan Hospital, Cheonan, South Korea.

[*] Correspondence: Ki Jin Jung, Department of Orthopaedic Surgery, Soonchunhyang University Cheonan Hospital, 31 Soonchunhyang 6-gil, Dongnam-gu, Cheonan-si, 31151, South Korea (e-mail: overmas99@hanmail.net).

How to cite this article: Shin BJ, Lee KM, Chung CY, Sung KH, Chun DI, Hong CH, Kim JB, Kwon SW, Kim WJ, Song MG, Yoon SJ, Jung KJ. Analysis of factors influencing improvement of idiopathic flatfoot. Medicine 2021;100:32(e26894).

Received: 6 January 2021 / Received in final form: 17 June 2021 / Accepted: 18 July 2021

http://dx.doi.org/10.1097/MD.0000000000026894

1. Introduction

Idiopathic flatfoot (also known as pes planus or planovalgus) is common in infants and children, and patients with this condition are frequently referred to pediatric orthopedic clinics.[1] Generally, flatfoot is defined as a weight-bearing foot with an abnormally low or absent longitudinal arch and a valgus heel position.[2] The prevalence of flatfoot differs with age.[3] Morley[4] documented flatfoot in 97% of 18-month-old infants, whereas only 4% of 10-year-old children had flatfoot. In a study analyzing footprints in >800 patients, flatfoot was noted in 54% of 3-year-old children and in 26% of 6-year-old children.[5] Taken together, these studies suggest that flatfoot is a physiologic process, and that the arch of the foot elevates spontaneously in most children during the first decade of life.[6]

The incidence of flatfoot increases with age and is consistently reported in the literature.[4–6] Despite flatfoot being a typical developmental process, parents are frequently concerned about the appearance of the foot that may rarely cause disability or may be clinically significant. Despite its prevalence, the definition of what exactly constitutes a flatfoot remains surprisingly debatable. Furthermore, while feet are observed to spontaneously improve with increasing age, the exact rate of improvement each year has not been demonstrated.[6,7] Moreover, there is no consensus as to what factors influence the rate of correction. Because of the lack of understanding on the natural evolution of the foot, parental concern and physician preference tend to drive the evaluation and subsequent management of flatfoot. This can lead to unnecessary treatment and spending for a condition that does not usually require intervention.

A few prospective studies have investigated the natural history of flatfoot. Nevertheless, the available literature does not fully elucidate those factors that influence the rate of spontaneous correction. To achieve a consensus as the rate of spontaneous improvement of flatfoot, the present study aimed to estimate the rate of spontaneous improvement of flatfoot and to analyze correlating factors.

2. Materials and methods

This study was approved by the Institutional Review Board of Soonchunhyang University Hospital, Cheonan, South Korea. We reviewed the records of patients examined between May 2013 and May 2019 so as to identify those factors associated with idiopathic flatfoot below 12 years of age; we tracked patients who had been followed for >6 months, and those for whom ≥2 (anteroposterior and lateral) weight-bearing bilateral radiographs of the foot had been obtained. Most patients visit our clinic because of their parents' concerns about the appearance of their feet and gait abnormality. Some patients complained of pain during walking. The diagnosis of flatfoot was made based on clinical data, reviews of history, and records of underlying diseases, as well documentation of physical examination. Patients were examined both in sitting and standing position. Flatfoot is a dynamic deformity that requires weightbearing to clarify the diagnosis. The valgus position of the heel and the lack of formation of a medial arch with full weightbearing in a neutral foot and ankle position are important factors in the diagnosis.[8,9] The results of true ankle dorsiflexion and Achilles tendon contracture assessment are also evaluated. Less than 10° of dorsiflexion indicates contracture of the Achilles tendon.[10] We included patients below 12 years of age with who had been followed for >6 months, and those for whom ≥2 (anteroposterior and lateral) weight-bearing bilateral radiographs of the foot had been obtained. We excluded patients with history of foot surgery and non-physiologic flatfoot, including muscular dystrophy, cerebral palsy, Marfan syndrome, vertical talus, and tarsal coalition. We analyzed several factors that might influence the rate of improvement of flatfoot.[2] Age, sex, initial body mass index (BMI), and Achilles tendon contracture were analyzed to identify the correlation of spontaneous improvement of flatfoot.

2.1. Radiographic measurements

Nine parameters that were considered to be clinically relevant in quantifying flatfoot were selected for the radiographic measurements from the studies we reviewed.[6,7,11–14] On the AP foot, weight-bearing radiographs, the AP talo-first metatarsal angle and talonavicular coverage angle were measured. Using the lateral foot weight-bearing radiographs, we measured the following 7 items: calcaneal pitch angle, tibiocalcaneal angle, lateral talocalcaneal angle, lateral talo-first metatarsal angle, metatarsal stacking angle, medial–lateral column ratio, and naviculocuboid overlap. We considered the reliability and validity of the radiographic parameters to be the most important criteria when choosing parameters to include in this study. Four radiographic parameters were finally chosen. We assessed the weight-bearing radiographs, the AP talo-first metatarsal angle and talonavicular coverage angle on the AP foot. On the lateral foot weight-bearing radiographs, we assessed the lateral talo-first metatarsal angle as well as the calcaneal pitch angle. The AP talo-first metatarsal angle is formed by the intersection of the line that bisects the first metatarsal and the midline axis of the talus. (Fig. 1A).[7] The talonavicular coverage angle is the angle between a line bisecting the anterior articular surface of the talus and another line bisecting the proximal articular surface of the navicular (Fig. 1B).[12] The lateral talo-first metatarsal angle is formed by the intersection of the line that bisects the first metatarsal and the midline axis of the talar head and neck.[7] The calcaneal pitch angle is the angle of the calcaneus and the inferior aspect of the foot (Fig. 2).[14] Reliability testing was conducted. Interobserver reliability was determined with the use of intraclass correlation coefficients (ICCs). Two orthopedic surgeons (KJJ, HJJ), with 14 and 3 years of orthopedic experience, respectively, measured the radiographs independently in a blinded fashion.

2.2. Statistical methods

The progression rates of the AP talo-first metatarsal angle, talonavicular coverage angle, lateral talo-first metatarsal angle, and calcaneal pitch angle were adjusted by multiple factors using a linear mixed model (LMM), with sex, BMI, and Achilles tendon contracture as the fixed effects and age and each subject as the random effects. The restricted maximum likelihood estimation was employed to produce unbiased estimators. The LMM was constructed to estimate the improvement rate by incorporating the linear age effect, sex, BMI, and Achilles contracture as covariates. The slope indicated the rate of improvement per year. Examination the individual pattern of the rate of angular correction along with the duration of follow-up, a model with a random slope and a random intercept was suggested. Linear age effect, sex effect, BMI effect, and Achilles contracture effect were integrated to estimate the spontaneous correction of flatfoot.[6,15]

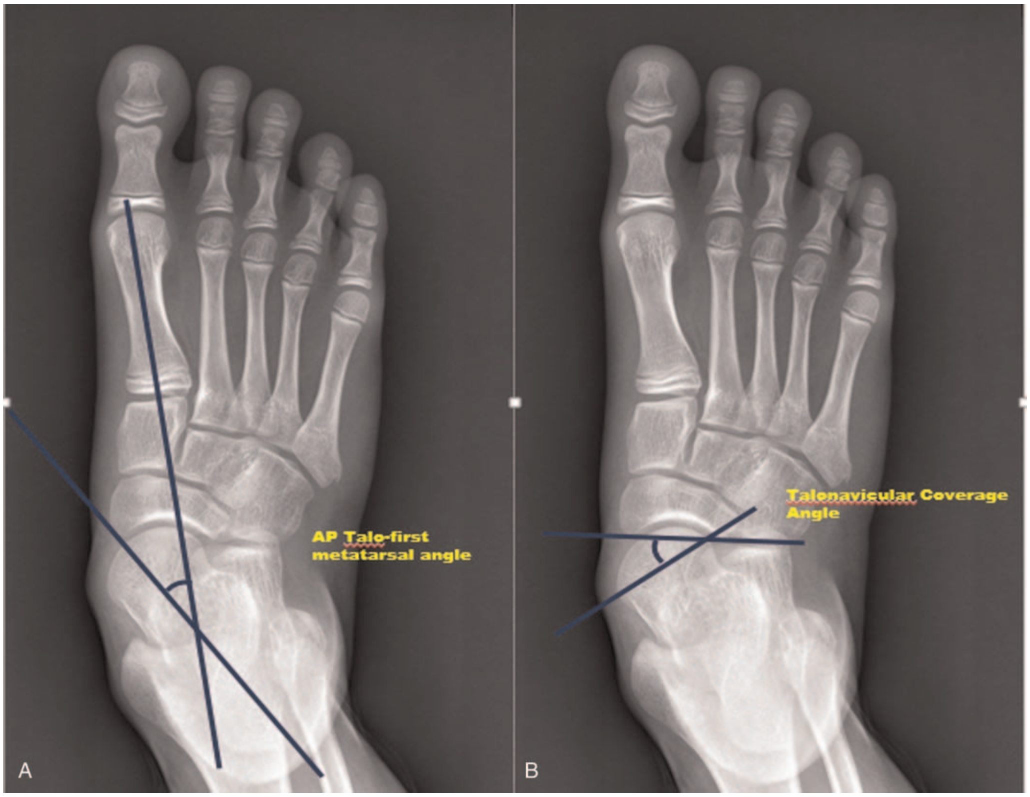

Figure 1. On the anteroposterior weight-bearing radiograph of the foot, the anteroposterior talonavicular (AP TN) coverage angle is the angle between a line bisecting the anterior articular surface of the talus and another line bisecting the proximal articular surface of the navicular bone.[7] The anteroposterior talus-first metatarsal (AP Talo-1MT) angle is formed by the intersection of the line that bisects the first metatarsal and the midline axis of the talus.[7]

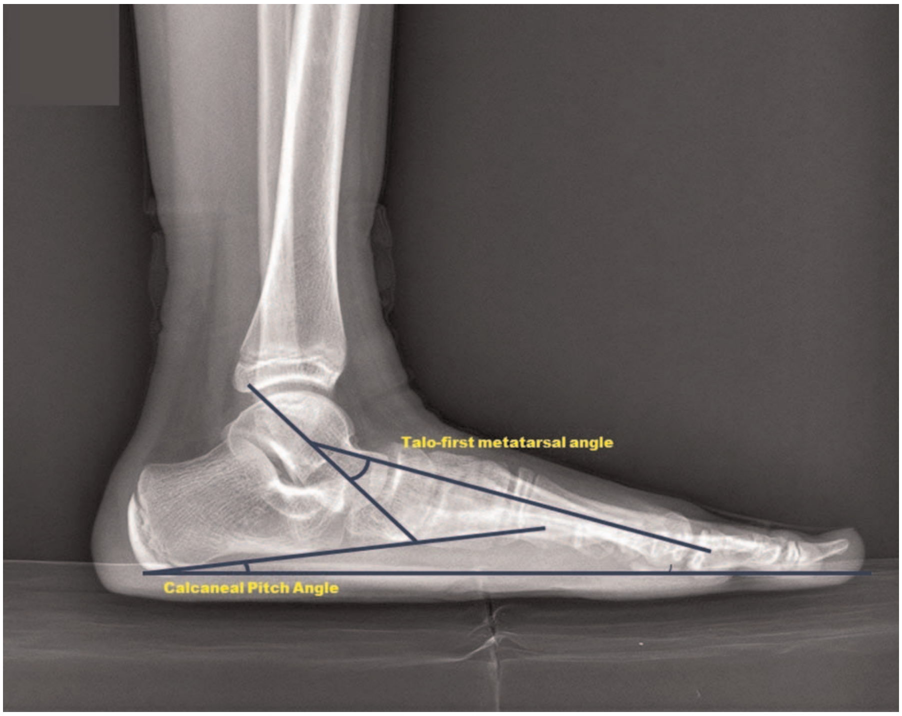

Figure 2. On the lateral weight-bearing radiograph of the foot, the calcaneal pitch (CP) angle is the angle of the calcaneus and the inferior aspect of the foot.[7] The lateral talus-first metatarsal (Lat Talo-1MT) angle is formed by the intersection of the line that bisects the first metatarsal and the midline axis of the talar head and neck.[7]

Table 1

Patient demographics.

Parameter	Value
No. subjects	176
Male/female, No.	110/66
No. of radiographs	1246
Achilles tendon contracture yes/no	17/159
Body mass index	23.5 (3.4)
Age at first visit, yrs	4.8 (3.1)
Follow-up duration, mo	17.1 (5.7)
Interval between follow-up, yrs	0.78 (0.55)
No. of follow-up	3.9 (1.1)

Data are presented as mean (SD).

We assessed reliability using ICCs and a 2-way random-effect model, assuming a single measurement and absolute agreement.[15,16] With the ICC target value of 0.8, a Bonett approximation was employed with 0.2 set as the width of 95% confidence intervals (CIs). The minimal sample size (number of radiographs needed) was calculated to be 36.[17] Patient demographics and radiographic measurements were summarized using descriptive statistics. We used a LMM to analyze the correction rates, assess the covariate effect, and investigate the factors that significantly contributed to the rate of correction.

Statistical analysis was performed using SPSS version 25.0 for Windows (SPSS Inc., Chicago, IL). Two-sided P-values < .05 were considered statistically significant.

3. Results

A total of 176 children (110 boys and 66 girls; mean age: 6.5 years, standard deviation: 2.8 years) were included in this study. A total of 1246 radiographs from 623 visits were analyzed (Table 1). The average follow-up period was 17.1 ± 5.7 months (range, 6–71 months). The mean age of the patients at the time of first outpatient visit was 4.8 ± 3.1 years (range, 1.8–10.6 years). The mean interval between follow-up evaluations was 0.78 ± 0.55 years (range, 6–47 months). The mean number of follow-up visits at our outpatient clinic was 3.9 ± 1.1 (range, 2–7 visits). We found that 4 of the radiographic measurements improved as patients grew older (Fig. 3A–D). The AP talo-first metatarsal angle, talonavicular coverage angle, and the lateral talo-first metatarsal angle decreased, while the calcaneal pitch increased by–0.7 (95% CI, −0.89 to −0.32; P < .001), −0.9 (95% CI, –1.24 to –0.5; P < .001), –1.1 (95% CI, –1.37 to –0.81; P < .001), and 0.6 (95% CI, –0.67 to 1.82; P = .367) per year, respectively (Table 2). The AP talo-first metatarsal angle, talonavicular coverage angle, and lateral talo-first metatarsal angle improved significantly; however, the calcaneal pitch angle did not show any significant difference. When comparing the right side and left side, a difference was observed. On the right side, the AP talo-first metatarsal angle, talonavicular coverage angle, and lateral talo-first metatarsal angle decreased, while the calcaneal pitch increased by −0.7 (95% CI, −0.99 to −0.35; P < .001), –1.0 (95% CI, –1.35 to –0.51; P < .001), –1.0 (95% CI, –1.32 to –0.67; P < .001), and 0.8 (95% CI, –1.74 to 3.22; P = .556) per year, respectively. On the right side, the rate of improvement of the calcaneal pitch angle with aging was not significant. On the left side, the AP talo-first metatarsal angle, talonavicular coverage angle, and lateral talo-first metatarsal angle decreased, while the calcaneal pitch increased by –0.6 (95% CI, –0.89 to –0.20; P = .002), –0.89 (95% CI, –1.24 to –0.37; P < .001), –1.09 (95% CI, –1.38 to –0.75; P < .001), and 0.57 (95% CI, 0.23–0.65; P < .001) per year, respectively. On the left side, the rates of improvement of all parameters were statistically significant (Table 3).

In general, the flatfeet showed an improving trend; after analyzing the factors, no sex difference was observed, while BMI and Achilles tendon contracture showed a negative correlation. For each factor, there was a difference of about 2° in each parameter for sex; this difference was not statistically significant (95% CI, –4.07–0.46; P = .117). For BMI, when the BMI increased by 1, the angle of each parameter increased from 0.5° to 1°. In other words, in any age and sex group, an increase in BMI negatively affects flatfoot improvement (95% CI, –0.28–0.75; P < .001). Each parameter related to Achilles tendon contracture increases by about 0.5° compared with the parameter in a person without Achilles tendon contracture. This may be because Achilles tendon contracture negatively affected flatfoot improvement (95% CI, 0.23–0.65; P < .001) (Table 3). All measurements showed excellent interobserver reliability. The measurements of the lateral talo-first metatarsal angle had the highest interobserver reliability (ICC, 0.910). By contrast, the measurements of the AP talo-first metatarsal angle had the lowest interobserver reliability (ICC, 0.871).

4. Discussion

We performed this study to measure the rate of spontaneous improvement of radiographic indices for flatfoot and to analyze the correlating factors. In the present study, the anteroposterior talo-first metatarsal angle, talonavicular coverage angle, and lateral talo-first metatarsal angle decreased by 0.7°, 0.9°, and 1.1° per year, respectively. The results of the present study correspond well with those of a previous study conducted by Vanderwilde, who reported that radiographs of the feet of 74 normal infants and children whose age ranged from 6 to 127 months showed spontaneous improvement of the foot arch.[7] Certain angles tended to decrease markedly with age (the AP talocalcaneal and calcaneus fifth metatarsal angle). Others decreased less sharply and less consistently (the lateral talocalcaneal and talo-first metatarsal angle). The results of the present study are quite similar to those of Park et al,[6] who assessed 3284 radiographs of 568 feet, and found that the talonavicular coverage angle decreased by 1.7° per year; the AP talo-first metatarsal angle decreased by 2.1° per year; and the lateral talo-first metatarsal angle decreased by 0.7° per year. These findings predict the spontaneous chronological radiographic improvement of flatfoot. There are several theories explaining the spontaneous improvement of flatfoot. Duchenne suggested that the coordinated and normal function of the muscles of the foot and ankle are responsible for the maintenance of the longitudinal arch and that subclinical muscle weakness typically improve with age.[18–20] This theory was refuted by Basmajian and Stecko,[21] who reported that the height of the longitudinal arch is determined based on the features of the bone ligament complex. Proponents of this bone ligament theory believe that the shape of the longitudinal arch under static loads is determined by the shape and interrelationship of the bones, coupled with the strength and flexibility of the ligaments.[21–23] Nevertheless, the development of flatfoot might be multifactorial. The relationships between bones, ligaments, and muscles of the foot, and overall limb

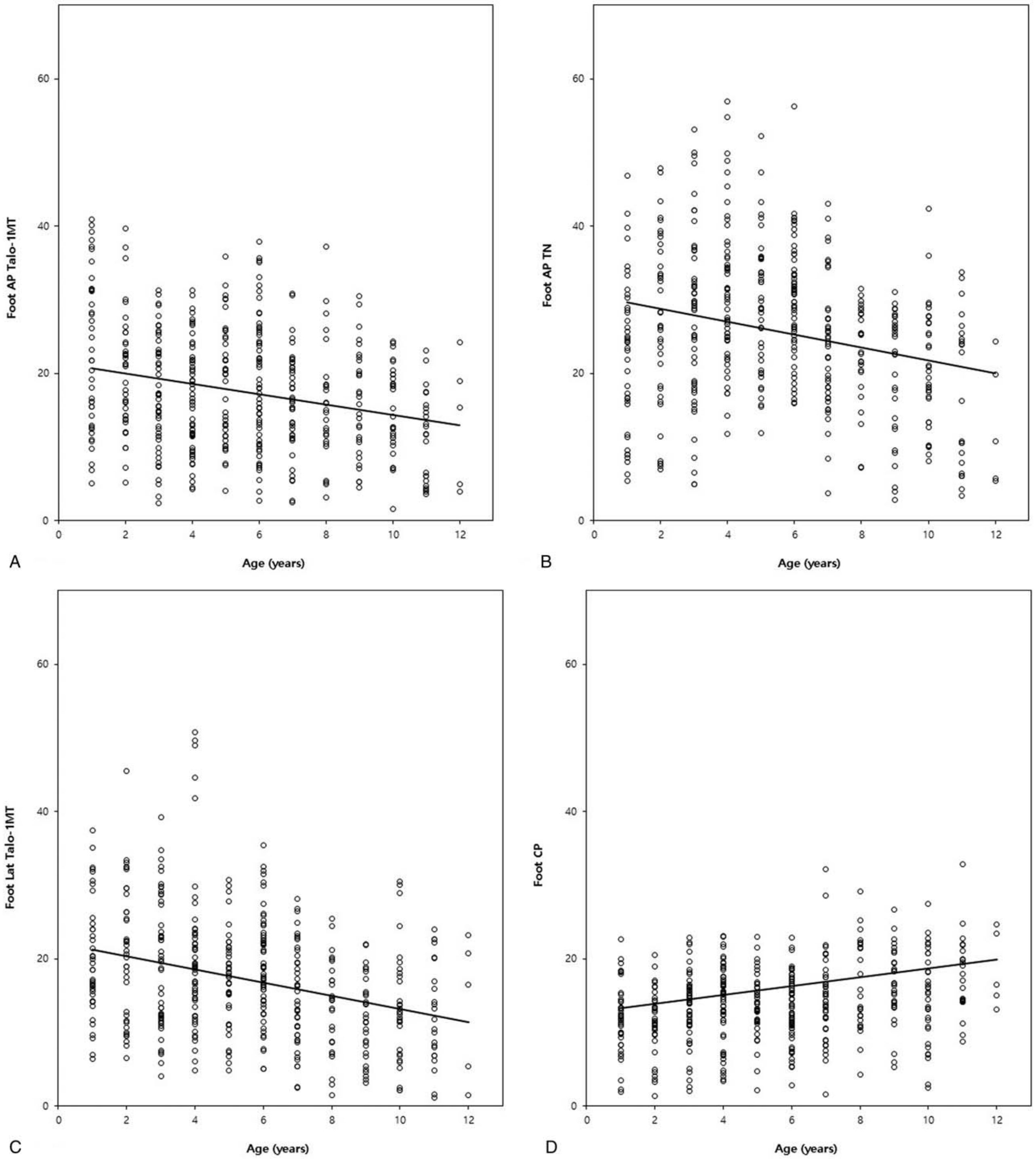

Figure 3. A–D, The reference values for the measured angles are shown. The solid lines represent the estimation of the improvement of each index by a linear age effect. A, The anteroposterior talo-first metatarsal (AP Talo-1MT) angle. B, The anteroposterior talonavicular angle. C, The lateral talo-first metatarsal (Lat Talo-1MT) angle. D, The calcaneal pitch angle.

alignment and comorbid medical conditions all may play key roles.

We analyzed the factors that influence the improvement of flatfoot. Although various factors were studied, BMI and Achilles tendon contracture were statistically significant negative factors. Several studies have reported greater BMI in patients with flatfoot. Evans and Karimi[24] examined the relationship between flatfoot and BMI in 825,964 generally healthy people. Obesity was associated with flatfeet. Flatfeet were present in 62% of obese children, 51% of overweight children, and 42% of young children with normal body weight. Similarly in adolescents, there is a greater prevalence of flexible flatfoot in men and in those with

Table 2

Estimation of radiographic indices with use of linear mixed model.

	Anteroposterior talo-first metatarsal angle			Talonavicular coverage angle		
	Estimation (95% CI)	SE	*P* value	Estimation (95% CI)	SE	*P* value
Intercept	21.61 (19.53–23.69)	1.06	<.001	29.44 (26.79–32.09)	1.35	<.001
Gender	–1.80 (–4.07–0.46)	1.15	.117	2.00 (–0.79–4.79)	1.41	.159
Age	–0.7 (–0.89 to –0.32)	0.14	<.001	–0.89 (–1.24 to –0.50)	0.19	<.001
BMI	0.42 (–0.28–0.75)	0.33	<.001	1.29 (–1.11–3.25)	1.78	.104
Contracture	0.44 (0.23–0.65)	0.11	<.001	0.32 (–0.14–0.75)	0.15	<.001
	Lasteral talo-first metatarsal angle			**Calcaneal pitch angle**		
	Estimation (95% CI)	**SE**	***P* value**	**Estimation (95% CI)**	**SE**	***P* value**
Intercept	23.00 (20.92–25.07)	1.05	<.001	13.59 (5.11–22.06)	4.30	.002
Gender	0.61 (–1.68–2.90)	1.16	.599	–2.14 (–10.08–5.80)	4.03	.596
Age	–1.09 (–1.37 to –0.81)	0.14	<.001	0.57 (–0.67–1.82)	0.63	.367
BMI	0.35 (–0.57 to 0.84)	0.33	.002	1.77 (–1.36–3.27)	1.13	.107
Contracture	0.34 (0.13–0.61)	0.17	<.001	0.31 (–0.38–1.75)	0.36	.053

CI = confidence interval, SE = standard error.

greater BMI. The presence of Achilles tendon contracture may prevent the normal dorsiflexion of the ankle joint, and the mechanical stress shifts to the subtalar joint. As the hindfoot deforms into valgus, the Achilles tendon is deviated laterally and shortens, leading to the development of contractures that in turn aggravate the deformity. According to the study of Harris and Beath, a foot examination performed in 3600 recruits in the Royal Canadian Army led to the detection of Achilles tendon contractures in 25% of participants with flatfoot, often accompanied by functional disability and pain.[22,25] A cadaveric study showed that the Achilles tendon contracture observed in several individuals with flatfeet may contribute to the severity of the deformity, particularly in longitudinal arch depression, forefoot abduction, and increased medial forefoot pressure.[26] A flexible flatfoot with a short Achilles tendon, by contrast to a simple flexible flatfoot, is known to cause pain and disability in some adolescents and adults.[10,22] Surgery is indicated in patients with flexible flatfeet with short Achilles tendons when conservative treatments fail to relieve pain.[10] Although these findings were not reported in our study, there were several factors associated with flatfoot. Recent articles have analyzed the factors that may predispose children to the development and persistence of flatfoot. Chen et al[27] found that higher joint laxity, W-sitting, male sex, obesity, and younger age were all associated with higher risk of developing a flatfoot in preschool children aged 3 to –6 years. Similarly, Chang et al[28] found that male sex and obesity were associated with a higher risk of developing a flatfoot in children aged 7 to 8 years. Other studies confirmed that obesity was associated with the persistence of flatfeet in older children and generalized joint laxity was another important factor that increased the risk of developing flatfoot.[3,29,30]

Some limitations of this study should be addressed. This study was retrospective in nature. Therefore, other factors such as generalized joint laxity and gait could not be analyzed. Moreover, this study used a small sample size, and relative short follow-up duration. This limitation could be complemented by further study.

Most of the patients with flatfoot are asymptomatic and do not require treatment. There remains considerable debate regarding the use of orthotics in patients with painless flatfoot. Randomized controlled trials and prospective cohort studies could not demonstrate the effects of orthotics on the medial longitudinal arch. They revealed that flexible flatfeet in young children slowly improved with age, regardless of the type of footwear used. Moreover, recent systematic reviews of the current literature demonstrated that there is very limited evidence supporting the efficacy of orthotics in children with flatfoot. Although 10% of American children with flatfeet are treated with orthoses, only 1% to 2% are symptomatic, suggesting that “greater than 90% of the treatments were unnecessary.”[3] Although many clinicians may believe that they are causing no harm by prescribing orthotics to patients with flexible flatfoot, long-term negative psychological effects have been demonstrated in adults who wore orthotics at a younger age.[31–33]

The study demonstrated that children’s flatfeet spontaneously improved at the age of 12 years. It would be more beneficial if the caregiver shows the predicted appearance of the foot at the completion of growth by calculating the radiographic indices and

Table 3

Estimation of radiographic indices with use of linear mixed model.

	Right side			Left side		
	Estimation (95% CI)	SE	*P* value	Estimation (95% CI)	SE	*P* value
Anteroposterior talo-first metatarsal angle	–0.7 (–0.99 to –0.35)	0.16	<.001	–0.6 (–0.89 to –0.20)	0.18	.002
Talonavicular coverage angle	–1.0 (–1.35 to –0.51)	1.15	<.001	–0.89 (–1.24 to –0.37)	0.22	<.001
Lasteral talo-first metatarsal angle	–1.0 (–1.32 to –0.67)	0.17	<.001	–1.09 (–1.38 to –0.75)	0.16	<.001
Calcaneal pitch angle	0.8 (–1.74–3.22)	1.26	.556	0.57 (0.23–0.65)	0.11	<.001

Comparing right and left side. CI = confidence interval, SE = standard error.

identifying the correlating factors in addition to explaining that flatfoot may gradually improve. This will prevent unnecessary medical expenses and the psychological adverse effects to the children caused by unnecessary treatment.

Acknowledgments

This research was supported by the Bio & Medical Technology Development Program of the National Research Foundation (NRF) funded by the Ministry of Science & ICT (2021M3E5D1A0201517321).

Author contributions

Conceptualization: Byung-Joon Shin, Kyoung Min Lee, Chin Youb Chung.
Formal analysis: Ki Hyuk Sung, Dong-Il Chun, Chang Hwa Hong.
Project administration: Chang Hwa Hong.
Software: Jun Bum Kim, Sai-Won Kwon.
Supervision: Ki Jin Jung.
Visualization: Sai-Won Kwon, Woo Jong Kim, Min Gon Song, Sung Joon Yoon.
Writing – original draft: Kyoung Min Lee, Chin Youb Chung.
Writing – review & editing: Byung-Joon Shin, Ki Jin Jung.

References

[1] Giannestras NJ. Recognition and treatment of flatfeet in infancy. Clin Orthop Relat Res 1970;70:10–29.
[2] Blitz NM, Stabile RJ, Giorgini RJ, DiDomenico LA. Flexible pediatric and adolescent pes planovalgus: conservative and surgical treatment options. Clin Podiatr Med Surg 2010;27:59–77.
[3] Pfeiffer M, Kotz R, Ledl T, Hauser G, Sluga M. Prevalence of flat foot in preschool-aged children. Pediatrics 2006;118:634–9.
[4] Morley AJ. Knock-knee in children. Br Med J 1957;2:976–9.
[5] Staheli LT, Chew DE, Corbett M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. J Bone Joint Surg Am 1987;69:426–8.
[6] Park MS, Kwon SS, Lee SY, Lee KM, Kim TG, Chung CY. Spontaneous improvement of radiographic indices for idiopathic planovalgus with age. J Bone Joint Surg Am 2013;95:e193, 1–8.
[7] Vanderwilde R, Staheli LT, Chew DE, Malagon V. Measurements on radiographs of the foot in normal infants and children. J Bone Joint Surg Am 1988;70:407–15.
[8] Stockley I, Betts RP, Rowley DI, Getty CJ, Duckworth T. The importance of the valgus hindfoot in forefoot surgery in rheumatoid arthritis. J Bone Joint Surg Br 1990;72:705–8.
[9] Benedetti MG, Ceccarelli F, Berti L, et al. Diagnosis of flexible flatfoot in children: a systematic clinical approach. Orthopedics 2011;34:94.
[10] Mosca VS. Flexible flatfoot in children and adolescents. J Child Orthop 2010;4:107–21.
[11] Davids JR, Gibson TW, Pugh LI. Quantitative segmental analysis of weight-bearing radiographs of the foot and ankle for children: normal alignment. J Pediatr Orthop 2005;25:769–76.
[12] Davitt JS, MacWilliams BA, Armstrong PF. Plantar pressure and radiographic changes after distal calcaneal lengthening in children and adolescents. J Pediatr Orthop 2001;21:70–5.
[13] Lee KM, Chung CY, Park MS, Lee SH, Cho JH, Choi IH. Reliability and validity of radiographic measurements in hindfoot varus and valgus. J Bone Joint Surg Am 2010;92:2319–27.
[14] Steel MW3rd, Johnson KA, DeWitz MA, Ilstrup DM. Radiographic measurements of the normal adult foot. Foot Ankle 1980;1:151–8.
[15] Lee KM, Lee J, Chung CY, et al. Pitfalls and important issues in testing reliability using intraclass correlation coefficients in orthopaedic research. Clin Orthop Surg 2012;4:149–55.
[16] Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979;86:420–8.
[17] Bonett DG. Sample size requirements for estimating intraclass correlations with desired precision. Stat Med 2002;21:1331–5.
[18] Haraldsson S. Pes plano-valgus staticus juvenilis and its operative treatment. Acta Orthop Scand 1965;35:234–56.
[19] Duchenne GB, Kaplan EB. Physiology of Motion. Philadelphia: WB Saunders; 1959. 337.
[20] Jones BS. Flat foot. A preliminary report of an operation for severe cases. J Bone Joint Surg Br 1975;57:279–82.
[21] Basmajian JV, Stecko G. The role of muscles in arch support of the foot. J Bone Joint Surg Am 1963;45:1184–90.
[22] Harris RI, Beath T. Hypermobile flat-foot with short tendo achillis. J Bone Joint Surg Am 1948;30A:116–40.
[23] Hicks JH. The mechanics of the foot. I. The joints. J Anat 1953;87: 345–57.
[24] Evans AM, Karimi L. The relationship between paediatric foot posture and body mass index: do heavier children really have flatter feet? J Foot Ankle Res 2015;8:46.
[25] Ueki Y, Sakuma E, Wada I. Pathology and management of flexible flat foot in children. J Orthop Sci 2019;24:9–13.
[26] Blackman AJ, Blevins JJ, Sangeorzan BJ, Ledoux WR. Cadaveric flatfoot model: ligament attenuation and Achilles tendon overpull. J Orthop Res 2009;27:1547–54.
[27] Chen KC, Yeh CJ, Tung LC, Yang JF, Yang SF, Wang CH. Relevant factors influencing flatfoot in preschool-aged children. Eur J Pediatr 2011;170:931–6.
[28] Chang JH, Wang SH, Kuo CL, Shen HC, Hong YW, Lin LC. Prevalence of flexible flatfoot in Taiwanese school-aged children in relation to obesity, gender, and age. Eur J Pediatr 2010;169:447–52.
[29] Napolitano C, Walsh S, Mahoney L, McCrea J. Risk factors that may adversely modify the natural history of the pediatric pronated foot. Clin Podiatr Med Surg 2000;17:397–417.
[30] Adoracion Villarroya M, Manuel Esquivel J, Tomas C, Buenafe A, Moreno L. Foot structure in overweight and obese children. Int J Pediatr Obes 2008;3:39–45.
[31] Driano AN, Staheli L, Staheli LT. Psychosocial development and corrective shoewear use in childhood. J Pediatr Orthop 1998;18:346–9.
[32] Pavone V, Testa G, Vescio A, et al. Diagnosis and treatment of flexible flatfoot: results of 2019 flexible flatfoot survey from the European Paediatric Orthopedic Society. J Pediatr Orthop B 2020;Publish Ahead of Print.
[33] Chen KC, Chen YC, Yeh CJ, Hsieh CL, Wang CH. The effect of insoles on symptomatic flatfoot in preschool-aged children: a prospective 1-year follow-up study. Medicine (Baltimore) 2019;98:e17074.