J. Phys. Ther. Sci. 29: 413–418, 2017

The Journal of Physical Therapy Science

Original Article

Evaluation of the relationship between the static measurement of transverse arch flexibility of the forefoot and gait parameters in healthy subjects

Takashi Kondo, RPT, MS[1, 2], Takeshi Muneta, MD, PhD[1]*, Tsutomu Fukui, RPT, PhD[2]

[1] *Department of Joint Surgery and Sports Medicine, Graduate School, Tokyo Medical and Dental University: 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8519, Japan*
[2] *Sports Management Center, Graduate School, Bunkyo Gakuin University, Japan*

Abstract. [Purpose] To investigate the relationship between the static measurement of the transverse arch of the forefoot, using a 3-dimensional (3D) foot scanner, and kinetics and kinematics of gait parameters in the sagittal plane. [Subjects and Methods] Twenty healthy subjects participated in this study. The transverse arch of the forefoot was measured under three conditions as follows: condition 1, sitting; condition 2, standing; and condition 3, foot forward and lower leg tilting anteriorly to the maximum position with heel contact. Gait parameters were recorded using a 3D motion analysis system and force plate. Correlation coefficients between TAF for each comparison of conditions and gait parameters were calculated using the Spearman correlation analysis. [Results] Rates of the transverse arch of the forefoot width and height between condition 2 and condition 3 were significantly correlated with the anterior and posterior component of ground reaction forces, the hip joint extension angle, and the ankle plantar flexion moment. [Conclusion] Our study's findings indicated that increased stiffness of the transverse arch of the forefoot was related to the increase in ankle plantar moment, and decreased stiffness of the transverse arch of the forefoot was related to the increase in hip joint extension angle during gait.

Key words: Static measurement, Transverse arch of the forefoot, Level walking

(This article was submitted Sep. 7, 2016, and was accepted Nov. 24, 2016)

INTRODUCTION

The foot consists of the medial and lateral longitudinal arches, and the transverse arch of the forefoot (TAF). The arch of the foot works as a shock absorber to attenuate weight loading during the early stance phase of gait. The arch also works as a rigid lever to propel body mass efficiency during the late stance phase of gait[1, 2]. Clinical measurements of foot arch structures are mainly obtained to evaluate the medial longitudinal arch using the arch height index and the navicular drop test[1, 3–6]. Several clinical research studies have reported on the relationship between athletic lower extremity disorders and the medial longitudinal arches of the foot. Knee joint disorders occurred more often in athletes with excessively pronated and supinated feet[7]. In long distance runners with a high arch feet, ankle joint disorders occur more often than in those without a high medial longitudinal arch, whereas in those with a low longitudinal medial arch, knee joint disorders occur more often[8, 9]. Furthermore, regarding relationships between the medial longitudinal arch and gait, some works of clinical research on the medial longitudinal arch found a correlation between the ground reaction force and structure of a medial arch during gait[10, 11]. However, the medial longitudinal arch did not have any correlation with plantar pressure and rear-foot motion during gait[12, 13]. Thus, no consensus has been reached about the relationship between the clinical measurements of foot posture and gait. Although the correlation between the clinical measurements of foot posture and gait has not been sufficiently investigated, clinicians assume that there is some correlation between the static measurement of foot posture and

---

*Corresponding author. Takeshi Muneta (E-mail: muneta.orj@tmd.ac.jp) gait, and they clinically apply this assumption when treating patients[10, 13, 14].

Clinically, there is much limitation to the evaluation of lateral longitudinal and transverse arches, except the medial longitudinal arch[15]. Clinical measurements of the forefoot are important, because forefoot deformity is highly correlated with lower leg pain and a risk of falling[16, 17]. Measurements of TAF, which is part of the forefoot structure, have been performed using plantar pressure measurements[18–20], ultrasonography[21, 22], and radiographic photography[23, 24]. Recently, a 3-dimensional (3D) foot scanner[25] has made it easier to measure TAF noninvasively. However, the relationship between static measurements of TAF and gait has not been well investigated. It has been reported that TAF spreads due to weight bearing placed on the forefoot during gait[18, 19]. Therefore, in adding the morphologic change measurements of TAF during weight bearing to the static measurements of TAF, the TAF becomes more efficiently understood during human activities.

Accordingly, the purpose of the present study was to investigate the relationship between the static measurement of TAF, using a 3D foot scanner, and kinetics and kinematics of gait parameters on the sagittal plane in healthy subjects. The results of this study may enable clinicians to more efficiently evaluate the TAF results of patients experiencing difficulties during daily activities. Moreover, the evaluation methods of TAF may be applied to elderly individuals who experience difficulty during gait. We hypothesized that static measurements of TAF are correlated to gait parameters (joint angle, joint moment, joint power, and ground reaction force).

SUBJECTS AND METHODS

Twenty subjects (10 men and 10 women) participated in this study. They were 22.6 ± 2.8 years old (mean ± SD [standard deviation]) and 166.0 ± 9.0 cm tall, and weighed 60.6 ± 11.1 kg. They had no lower extremity pain and disorders. We defined the dominant side as the side subjects' used to kick a ball. All subjects in this study provided written informed consent, and the protocol was approved by the ethics committee of the Bunkyo Gakuin University Graduate School (approval No.: 2014-MSJ01).

TAF was measured using a 3D foot scanner (INFOOT; I-Ware Laboratory, Osaka, Japan). Three conditions were used to measure TAF: sitting (condition 1), standing (condition 2), and foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact (condition 3) (Fig. 1)[1, 5, 6, 26]. These conditions of foot posture can be frequently and reproducibly used in human activities, and applied easily in clinical settings. We confirmed weight bearing under each condition using a scale during the measurements; condition 1 is 10% of body weight, condition 2 is 50% of body weight, and condition 3 is 70–80% of body weight on the dominant foot[1, 26]. Furthermore, we confirmed that each subject could carry his/her weight on the forefoot in condition 3. Only the dominant foot was measured three times under each condition. We recorded the TAF width and height at the level of the metatarsal head for each measurement. Values of the TAF width and height were calculated as a mean value of thrice TAF measurements. The TAF width and TAF height were calculated between condition 1 and condition 2, and between condition 2 and condition 3, as the rate of each comparison, i.e., %width and %height, respectively. We calculated the rate of the TAF width using the following equations: between condition 1 and condition 2 = [(TAF width of condition 2) / (TAF width of condition 1) × 100], and between condition 2 and condition 3 = [(TAF width of condition 3) / (TAF width of condition 2) × 100]. We also calculated the rate of the TAF height using the following equations: between condition 1 and condition 2 = [(TAF height of condition 1 − TAF height of condition 2) / (TAF height of condition 1) × 100], and between condition 2 and condition 3 = [(TAF height of condition 2 − TAF height of condition 3) / (TAF height of condition 2) × 100].

Body kinematics measurements were performed using eight cameras (Vicon Motion Systems, Ltd., Oxford, UK) at a sampling rate of 100 Hz. Subjects were clothed in close-fitting t-shirts and shorts. Reflective markers were attached to the body according to the marker position of the Vicon Plug-in Gait full body model by a single investigator. All data were obtained with a low-pass filter using a fourth-order Butterworth filter with a cut-off frequency of 6 Hz. A force plate (AMTI, Watertown, MA, USA) was used to measure the ground reaction force at a sampling rate of 1,000 Hz. Subjects were asked to walk at a pace of 110 steps/min in bare feet. Before the measurements, each subject practiced the proper walking technique. The gait performance was determined as successful when the dominant foot completely touched the force plate. The gait trial was repeated to achieve successful gait five times. We recorded data from the stance phase during gait in each trial. Peak values of the joint angles; joint moments; joint powers of the hip, knee, and ankle joint; and ground reaction force in the sagittal plane were calculated using a Plug-in-Biomechanical Modeler (Vicon Motion Systems, Ltd.). The joint moments were expressed as an internal moment. Peak values of the joint power were labeled according to a previous study[27]. Values of the joint moment, joint power, and ground reaction force were normalized with regard to a subject's body mass. The mean value of five successful trials was used for analysis.

The Shapiro-Wilk test was used to determine whether all data followed a normal distribution. Subsequently, we calculated correlation coefficients between the TAF width (%); TAF height (%) for each comparison of conditions; and joint angle, joint moment, joint power, and ground reaction force during gait using the Spearman correlation analysis. All data were analyzed using SPSS 21.0 (SPSS Japan Inc., Tokyo, Japan). The statistical significance was set at $p<0.05$.

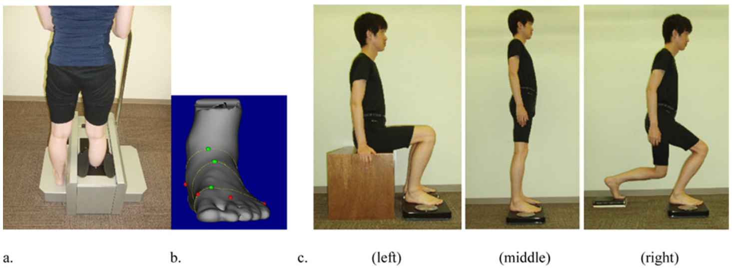

Fig. 1. Evaluation of foot posture using the 3-dimensional foot scanner (INFOOT; I-Ware Laboratory, Osaka, Japan) under three posture conditions for transverse arch measurements of the forefoot
a. Evaluation apparatus, b. measured image of the foot, and c. evaluated postures. Condition 1 (left): sitting, condition 2 (middle): standing, and condition 3 (right): foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact. Weight bearing of the dominant foot is measured at each condition: 10% body weight in condition 1, 50% body weight in condition 2, and 70–80% body weight in condition 3.

Table 1. The mean values of TAF width and TAF height at each condition (means ± SD)

	Measurement conditions		
	Condition 1	Condition 2	Condition 3
TAF width (mm)	96.2 ± 6.4	98.4 ± 6.8	99.5 ± 7.5
TAF height (mm)	40.8 ± 4.5	39.1 ± 4.3	38.6 ± 4.4

TAF: transverse arch of the forefoot
Condition 1: sitting, Condition 2: standing, Condition 3: foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact

Table 2. The mean change of TAF width and TAF height between two conditions (means ± SD)

	Measurement conditions	
	Condition 1 to Condition 2	Condition 2 to Condition 3
TAF width (%)	102.3 ± 0.7	100.9 ± 1.2
TAF height (%)	4.4 ± 1.9	0.84 ± 3.1

TAF: transverse arch of the forefoot
Condition 1: sitting, Condition 2: standing, Condition 3: foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact

RESULTS

The average values of TAF height and TAF width are shown in Table 1. The average change in the TAF width and TAF height is shown in Table 2 between condition 1 and condition 2, and between condition 2 and condition 3.

Regarding the change between condition 1 and condition 2, there was no significant correlation between the change in the TAF width and TAF height, and the gait variables, i.e., the joint angle, joint moment, joint power, and ground reaction force. Regarding the change between condition 2 and condition 3, there were significant correlations between changes in the TAF width and the anterior ($r=0.54$) and posterior component ($r=0.56$) of the ground reaction forces, and hip joint extension angles ($r=0.40$). Additionally, there were significant correlations between changes in the TAF height and ankle plantar flexion moment ($r=-0.46$) (Table 3).

DISCUSSION

This study showed the static measurements of TAF were correlated to ground reaction forces, ankle plantar flexion moment, and hip extension angle during gait. Therefore, the results of this study supported our hypothesis. The change in TAF between condition 1 (sitting) and condition 2 (standing) was not correlated with any gait parameters. The change in TAF between standing (condition 2) and foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact (condition 3) was statistically correlated with the anterior and posterior component of ground reaction forces, hip extension angle, and ankle plantar flexion moment during gait. Therefore, these results suggest that it will be useful to evaluate changes in TAF between condition 2 and condition 3 to assess foot disorders and gait performances. Previous research studies[28, 29)] have reported that additional weight bearing causes a change in foot posture. However, the change in TAF between condition 1 and condition 2 seems too small, i.e., body weight change of only 50% was not large enough to make the morphologic change detectable during an evaluation, or sufficient weight was not placed to the forefoot. Consequently, the change in TAF between condition 1 and condition 2 was not significantly detectable during the gait performances. Although static measurements of the medial longitudinal arch have been obtained clinically using sitting or standing as a measurement position, the current study's results suggest that a sufficient amount of weight bearing is necessary to achieve detectable changes in TAF to evaluate arch changes of the foot during gait performance.

Table 3. Correlation coefficients between changes of TAF width and TAF height, and joint angle, joint moment and ground reaction force during gait

Measurement conditions	Rates of TAF	The peak of joint angles					
		Hip joint		Knee joint		Ankle joint	
		flex	ext	flex	ext	dorsi	plantar
Condition 1 to Condition 2	TAF width	−0.09	0.09	−0.04	0.13	0.08	0.19
	TAF height	−0.14	−0.06	0.15	0.15	−0.05	−0.15
Condition 2 to Condition 3	TAF width	0.07	0.40*	−0.02	0.02	−0.10	0.17
	TAF height	−0.01	−0.01	0.09	−0.10	0.16	−0.22

Measurement Condition s	Rates of TAF	The peak of joint moments						
		Hip joint		Knee joint			Ankle joint	
		ext	flex	ext (early stance)	flex	ext (late stance)	dorsi	plantar
Condition 1 to Condition 2	TAF width	0.14	0.32	0.22	0.06	0.18	0.03	0.18
	TAF height	−0.17	−0.23	−0.38	−0.1	−0.07	−0.39	0.01
Condition 2 to Condition 3	TAF width	0.04	−0.15	0.25	0.02	−0.20	−0.11	−0.11
	TAF height	0.14	0.07	0.29	−0.18	0.07	0.09	−0.46*

Measurement Condition s	Rates of TAF	The peak of ground reaction forces				
		Anterior component		Vertical component		
		Min	Max	Max (early stance)	Min	Max (late stance)
Condition 1 to Condition 2	TAF width	0.01	0.13	0.12	−0.05	0.05
	TAF height	−0.18	−0.33	−0.37	0.22	−0.24
Condition 2 to Condition 3	TAF width	0.56*	0.54*	0.35	−0.30	0.23
	TAF height	0.08	−0.09	0.13	−0.07	0.01

TAF: transverse arch of the forefoot

Condition 1: sitting, Condition 2: standing, Condition 3: foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact

flex: flexion, ext: extension, dorsi: dorsiflexion, plantar: plantarflexion

*p<0.05

Regarding the relationship between the change in TAF and gait parameters, the change in TAF between condition 2 and condition 3 was significantly correlated with the anterior and posterior component of ground reaction forces during gait. The posterior component of the ground reaction force matches the timing of weight bearing and shock absorption during the early stance phase30), which suggests that the smooth, rapid spreading of TAF is important for posture stability in the early stance phase of gait. Moreover, since the anterior component of the ground reaction force increases weight bearing on the forefoot and moves body mass forward30), the change in TAF between condition 2 and condition 3 may be an indicator of the driving force of body mass during gait. Previous works of research have reported that TAF spreads during gait due to weight bearing18, 19, 31), and the TAF width increases while the TAF height decreases due to weight bearing29). Thus, changes in the TAF width and height between condition 2 and condition 3 would be an indicator for the tendency of forefoot spreading with weight bearing in each subject. Furthermore, the change in the TAF height between condition 2 and condition 3 was significantly correlated with ankle plantar flexion moment. Since ankle plantar flexion moment contributes as a driving force of body mass during the late stance phase32, 33), the lesser change in the TAF height between condition 2 and condition 3 suggests a larger driving force of body mass by ankle plantar flexion during the late stance of gait.

When the change in the TAF width and height in this study is considered the stiffness of TAF, the larger increase in TAF means a low stiffness of TAF, whereas the lower increase in TAF represents a high stiffness of TAF. Therefore, when the increase in TAF is considered the stiffness of TAF, the results of the study indicate that the subjects with a low stiffness of TAF walk with low ankle plantar flexion moment and have a large hip extension angle, whereas subjects with a high stiffness of TAF walk with high ankle plantar flexion moment and have a small hip extension angle. Previous research studies have reported that individuals with a high arch foot with high stiffness produce greater work of the ankle joint during landing and jogging, whereas individuals with a low arch foot with low stiffness produce greater work of the hip joint to overcome the reduced efficacy of a flexible foot34, 35). The current study's findings showed the same relationships as those reported in previous studies34, 35) that investigated the relationship between TAF stiffness and function of the hip joint and ankle joint during gait. Moreover, elderly people walk with higher hip joint movement36), so the TAF of this population is easily lowered during weight bearing37). Therefore, the same relationships between TAF stiffness and characteristics of gait performance would be indicated in elderly people, as this study demonstrated. The positive correlation between high stiffness of the TAF and ankle plantar flexion moment may partly explain the factors of the medial tibial stress syndrome, as a previous study indicated relationships between high stiffness of the TAF and medial tibial stress syndrome38).

There are some limitations to this study. Only healthy subjects participated in this study, so we did not consider cases of elderly individuals with foot deformities. We only analyzed gait performance in this study, so we did not understand relationships between TAF flexibility and sports performances, and other human body motion. Further research with participated elderly individuals and patients with foot deformities should confirm our findings.

In summary, the static measurement of TAF between standing and foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact was more related to gait parameters than between sitting and standing. The change in TAF between standing and foot forward and lower leg tilting anteriorly to the maximum ankle dorsiflexion with heel contact suggests that increasing TAF stiffness was related to the increase in the ankle plantar moment, and decreasing TAF stiffness was related to the increase in the hip joint extension angle during gait.

REFERENCES

1) Zifchock RA, Davis I, Hillstrom H, et al.: The effect of gender, age, and lateral dominance on arch height and arch stiffness. Foot Ankle Int, 2006, 27: 367–372. [Medline]
2) Kothari A, Dixon PC, Stebbins J, et al.: Motion analysis to track navicular displacements in the pediatric foot: relationship with foot posture, body mass index, and flexibility. Foot Ankle Int, 2014, 35: 929–937. [Medline] [CrossRef]
3) Nilsson MK, Friis R, Michaelsen MS, et al.: Classification of the height and flexibility of the medial longitudinal arch of the foot. J Foot Ankle Res, 2012, 5: 3. [Medline] [CrossRef]
4) Menz HB: Alternative techniques for the clinical assessment of foot pronation. J Am Podiatr Med Assoc, 1998, 88: 119–129. [Medline] [CrossRef]
5) Williams DS, McClay IS: Measurements used to characterize the foot and the medial longitudinal arch: reliability and validity. Phys Ther, 2000, 80: 864–871. [Medline]
6) Razeghi M, Batt ME: Foot type classification: a critical review of current methods. Gait Posture, 2002, 15: 282–291. [Medline] [CrossRef]
7) Dahle LK, Mueller MJ, Delitto A, et al.: Visual assessment of foot type and relationship of foot type to lower extremity injury. J Orthop Sports Phys Ther, 1991, 14: 70–74. [Medline] [CrossRef]
8) Williams DS 3rd, McClay IS, Hamill J: Arch structure and injury patterns in runners. Clin Biomech (Bristol, Avon), 2001, 16: 341–347. [Medline] [CrossRef]
9) Chuter VH, Janse de Jonge XA: Proximal and distal contributions to lower extremity injury: a review of the literature. Gait Posture, 2012, 36: 7–15. [Medline] [CrossRef]
10) Franettovich MM, McPoil TG, Russell T, et al.: The ability to predict dynamic foot posture from static measurements. J Am Podiatr Med Assoc, 2007, 97: 115–120. [Medline] [CrossRef]
11) Teyhen DS, Stoltenberg BE, Collinsworth KM, et al.: Dynamic plantar pressure parameters associated with static arch height index during gait. Clin Biomech (Bristol, Avon), 2009, 24: 391–396. [Medline] [CrossRef]
12) McPoil TG, Cornwall MW: The relationship between static lower extremity measurements and rearfoot motion during walking. J Orthop Sports Phys Ther, 1996, 24: 309–314. [Medline] [CrossRef]
13) Jonely H, Brismée JM, Sizer PS Jr, et al.: Relationships between clinical measures of static foot posture and plantar pressure during static standing and walking. Clin Biomech (Bristol, Avon), 2011, 26: 873–879. [Medline] [CrossRef]
14) McPoil TG, Vicenzino B, Cornwall MW, et al.: Reliability and normative values for the foot mobility magnitude: a composite measure of vertical and medial-lateral mobility of the midfoot. J Foot Ankle Res, 2009, 2: 6. [Medline] [CrossRef]
15) Tong JW, Kong PW: Association between foot type and lower extremity injuries: systematic literature review with meta-analysis. J Orthop Sports Phys Ther, 2013, 43: 700–714. [Medline] [CrossRef]
16) Benvenuti F, Ferrucci L, Guralnik JM, et al.: Foot pain and disability in older persons: an epidemiologic survey. J Am Geriatr Soc, 1995, 43: 479–484. [Medline] [CrossRef]
17) Gorter K, Kuyvenhoven M, de Melker R: Health care utilisation by older people with non-traumatic foot complaints. What makes the difference? Scand J Prim Health Care, 2001, 19: 191–193. [Medline] [CrossRef]
18) Luger EJ, Nissan M, Karpf A, et al.: Patterns of weight distribution under the metatarsal heads. J Bone Joint Surg Br, 1999, 81: 199–202. [Medline] [CrossRef]
19) Kanatli U, Yetkin H, Bolukbasi S: Evaluation of the transverse metatarsal arch of the foot with gait analysis. Arch Orthop Trauma Surg, 2003, 123: 148–150. [Medline]
20) Weijers RE, Walenkamp GH, Kessels AG, et al.: Plantar pressure and sole thickness of the forefoot. Foot Ankle Int, 2005, 26: 1049–1054. [Medline]
21) Tschauner C, Kohlmaie W: Ultrasonographic evaluation of the transverse metatarsal arch. Foot Ankle Surg, 1997, 3: 41–48. [CrossRef]
22) Daentzer D, Wülker N: Observations concerning the transverse metatarsal arch. Foot Ankle Surg, 1997, 3: 15–20. [CrossRef]
23) Suzuki J, Tanaka Y, Takaoka T, et al.: Axial radiographic evaluation in hallux valgus: evaluation of the transverse arch in the forefoot. J Orthop Sci, 2004, 9: 446–451. [Medline] [CrossRef]
24) Simonsen O, Vuust M, Understrup B, et al.: The transverse forefoot arch demonstrated by a novel X-ray projection. Foot Ankle Surg, 2009, 15: 7–13. [Medline] [CrossRef]
25) Mochimaru M, Kouchi M: Shoe customization based on 3D deformation of a digital human. The Engineering of Sport 4th International Conference, 2002, 4: 595–601.

26) Kudo S, Hatanaka Y, Naka K, et al.: Flexibility of the transverse arch of the forefoot. J Orthop Surg (Hong Kong), 2014, 22: 46–51. [Medline] [CrossRef]
27) Eng JJ, Winter DA: Kinetic analysis of the lower limbs during walking: what information can be gained from a three-dimensional model? J Biomech, 1995, 28: 753–758. [Medline] [CrossRef]
28) Tsung BY, Zhang M, Fan YB, et al.: Quantitative comparison of plantar foot shapes under different weight-bearing conditions. J Rehabil Res Dev, 2003, 40: 517–526. [Medline] [CrossRef]
29) Xiong S, Ravindra S: Foot deformations under different load-bearing conditions and their relationships to stature and body weight. Anthropol Sci, 2009, 117: 77–88. [CrossRef]
30) Perry J: Gait analysis normal and pathological function. California: Downey, 1992, pp 413–429.
31) Yang S: Dynamic Changes of the Arches of the Foot during Walking. Acta Med Nagasaki, 1985, 30: 93–112.
32) Kepple TM, Siegel KL, Stanhope SJ: Relative contributions of the lower extremity joint moments to forward progression and support during gait. Gait Posture, 1997, 6: 1–8. [CrossRef]
33) Meinders M, Gitter A, Czerniecki JM: The role of ankle plantar flexor muscle work during walking. Scand J Rehabil Med, 1998, 30: 39–46. [Medline] [CrossRef]
34) Powell DW, Williams DS 3rd, Windsor B, et al.: Ankle work and dynamic joint stiffness in high- compared to low-arched athletes during a barefoot running task. Hum Mov Sci, 2014, 34: 147–156. [Medline] [CrossRef]
35) Powell DW, Queen RM, Williams DS 3rd: Arch structure is associated with unique joint work, relative joint contributions and stiffness during landing. Hum Mov Sci, 2016, 49: 141–147. [Medline] [CrossRef]
36) Riley PO, DellaCroce U, Kerrigan DC: Effect of age on lower extremity joint moment contributions to gait speed. Gait Posture, 2001, 14: 264–270. [Medline] [CrossRef]
37) Tomassoni D, Traini E, Amenta F: Gender and age related differences in foot morphology. Maturitas, 2014, 79: 421–427. [Medline] [CrossRef]
38) Kudo S, Hatanaka Y: Forefoot flexibility and medial tibial stress syndrome. J Orthop Surg (Hong Kong), 2015, 23: 357–360. [Medline] [CrossRef]