İzmir Kâtip Çelebi Üniversitesi Sağlık Bilimleri Fakültesi Dergisi 2024; 9(3): 331-339
DOI: 10.61399/ikcusbfd.1283544
İKÇÜSBFD

RESEARCH / ARAŞTIRMA

Correlation of Radiological and Pedobarographic Evaluations in the Presence of Foot Sole Pain

Ayak Taban Ağrısı Varlığında Radyolojik ve Pedobarografik Değerlendirmelerin Korelasyonu

Dilek BAYRAKTAR[1], Selnur NARİN[2], Mehmet Halit ÖZYALÇIN[1]

[1] *Ege Üniversitesi Tıp Fakültesi Ortopedi ve Travmatoloji Kliniği, İzmir, Türkiye*
[2] *Dokuz Eylül Üniversitesi Fizik Tedavi ve Rehabilitasyon Fakültesi, İzmir, Türkiye*

Geliş tarihi/Received: 15.04.2023
Kabul tarihi/Accepted: 03.11.2024

Sorumlu Yazar/Corresponding Author:

Dilek BAYRAKTAR, Dr. Fzt.
Ege Üniversitesi Tıp Fakültesi Ortopedi ve Travmatoloji Kliniği Bornova İZMİR
E-posta: dilekbayraktar8@gmail.com
ORCID: 0000-0002-3200-7456

Selnur NARİN, Doç. Dr.
ORCID: 0000-0001-8781-7918

Mehmet Halit ÖZYALÇIN, Prof. Dr.
ORCID: 0000-0001-8122-8178

Abstract

Objective: One of the reasons for foot pain is the changes in the structure of the medial longitudinal arch. Assessment of medial longitudinal arch height is often made with foot radiographs and pedobarographic measurements. The relationship between these methods in the presence of foot sole pain has not been examined yet. This study aims to investigate the relationship among these measurement methods in adults with foot sole pain.

Materials and Methods: 60 adults with foot sole pain were included in this study. The talohorizontal, talocalcaneal, talo1.metatarsal, and calcaneal inclination angles were measured in the lateral weight bearing foot radiographs. The arch index was calculated in static, dynamic pedobarographic measurements. The agreement of radiological and pedographic measurements among themselves and with each other was determined.

Results: The mean age of 60 participants was 45.32 ±13.64. Agreement among foot classifications of radiologic measurements was poor Gwet's agreement coefficient =-0.198 with a 95% confidence interval (-0.315,-0.080); percent agreement = 0.167 with a 95% confidence interval (0.099,0.234) and Kappa =-0.047 with a 95% confidence interval (-0.083,-0.01) were found. The agreement between pedobarographic classifications was fair Gwet's agreement coefficient =0.486 with a 95% confidence interval (0.355,0.617); percent agreement =0.65 with 95% confidence interval (0.563,0.737) and Kappa=0.453 with a 95% confidence interval (0.324,0.583) were found. Among radiological measurements, the calcaneal inclination angle showed the highest coefficients of agreement with pedobarographic measurements. The extent of its agreement was fair.

Conclusion: Pedobarography is a simple, reliable, inexpensive, and noninvasive method. The calcaneal inclination angle which is used in radiological imaging can give an idea about the height of the medial longitudinal arch.

Keywords: Foot pain, medial longitudinal arch, pedobarographic arch index, radiologic measurements

Öz

Amaç: Ayak ağrısının nedenlerinden biri medial longitudinal arkın yapısındaki değişikliklerdir. Medial longitudinal arkın yüksekliğinin değerlendirilmesi sıklıkla ayak grafileri ve pedobarografik ölçümlerle yapılır. Ayak tabanı ağrısı varlığında bu yöntemlerin ilişkisi henüz incelenmemiştir. Bu çalışmanın amacı ayak taban ağrılı erişkinlerde bu yöntemler arasındaki ilişkiyi araştırmaktır.

Gereç ve Yöntem: Bu çalışmaya ayak taban ağrılı 60 yetişkin dahil edildi. Lateral yüklenmede ayak grafilerinde talohorizontal, talocalcaneal, talo1.metatarsal, kalkaneal eğim açıları ölçüldü. Ark indeksi, statik, dinamik pedobarografik ölçümlerde hesaplandı. Radyolojik ve pedografik ölçümlerin kendi aralarında ve birbirleri ile uyumu belirlendi.

Bulgular: 60 katılımcının yaş ortalaması 45.32 ±13.64 idi. Radyolojik ölçümlerin ayak sınıflandırmaları arasındaki %95 güven aralığı ile (-0.315,-0.080) Gwet'in uyum katsayısı=-0.198; %95 güven aralığı ile uyum yüzdesi = 0,167 (0,099,0,234) ve %95 güven aralığı ile Kappa=-0,047 (-0,083, -0,01) uyum zayıftı. Pedobarografik sınıflandırmalar arasındaki uyum, %95 güven aralığı ile (0,355,0,617) Gwet'in uyum katsayısı=0,486; %95 güven aralığı ile (0,563,0,737) uyum yüzdesi=0,65 ve %95 güven aralığı ile Kappa=0,453 (0,324,0,583) uyum orta düzeyde idi. Radyolojik ölçümler arasında kalkaneal eğim açısı, pedobarografik ölçümlerle en yüksek uyum katsayılarını sahipti. Kendi içindeki uyum "zayıf" tı.

Sonuç: Pedobarografi basit, güvenilir, ucuz ve girişimsel olmayan bir yöntemdir. Radyolojik görüntülemede kullanılan kalkaneal eğim açısı, medial longitudinal arkın yüksekliği hakkında fikir verebilir.

Anahtar Kelimeler: Ayak ağrısı, medial longitudinal ark, pedobarografik ark index, radyolojik ölçümler.

1. Introduction

As an important burden in health insurance systems, foot sole pain (FSP) is defined as a risk factor for decreased walking distance, loss of balance, increased risk of falling, and poor quality of life. Gates et al. (1) found the incidence of foot pain in society to be between 13% and 36% in their study. One of the causes of foot pain is changes in medial longitudinal arch (MLA) height (2). MLA consists of static and dynamic components such as muscles, bones, tendons, and ligaments (3). This structure reminds the arrangement of stones forming a Roman arch and so this formation is quite rigid (4). While MLA adapts to the ground in the mid-stance phase of walking (4) and takes the task of shock absorption and force transmission (2) it is highly important as it allows (in providing) the foot to act like a rigid lever during toe lift (5). Changes in MLA height are thought to trigger the injuries (6). The increase in MLA height creates a pes cavus (PC) deformity in the sagittal plane of the foot (7). In PC feet, the contact of the middle of the foot with the surface of the ground decreases (8). Pes planus (PP) is characterized by a decrease in the height of MLA (9). PC is seen in 10.5-25% and PP in 19-37% of the adult population (10,11). While injuries are assumed to occur in the bony structures on the lateral side of the foot in PC feet, they are thought to possibly occur in the soft tissues in the medial side of the foot in PP (12). Therefore, MLA should be evaluated accurately and easily. Many different methods are used in the evaluation of MLA height directly and indirectly. Visual observation, clinical measurements, radiograms, and footprints are among these methods (2,12,13). Among all these methods, there is no evaluation technique that is the gold standard (13). Many angular measurement techniques in weight-bearing foot X-rays are accepted as a direct evaluation method in the literature (14). These measurements help evaluate bone alignment and identify pathologies that cause foot pain. However, the overlapping of bone structures in radiological imaging is misleading due to the extreme sensitivity to beam angle deviation during distortion and imaging (15). Moreover, it does not allow dynamic evaluation of the foot (16,17). Today, the frequency of the use of pedobarographic devices has increased to better understand foot, and ankle pathologies (16). In measurements made with pedobarography devices, it transfers three-dimensional images and pressure distributions of the foot sole during standing and especially walking to the computer system with electronic sensors placed on the platform. Objective measurements made with the use of these data are called arch index measurements (18, 19). In addition, pedobarographic measurements provide objectivity, patient-specific assessment, and specific diagnosis (17). In this study, we hypothesized that in the presence of FSP, there is a difference between pedobarography, a dynamic method, and radiographic MLA evaluation methods, a static method. We tried to determine the difference between measurements by investigating the compatibility between static, dynamic pedobarographic arch index (AI) measurements and the lateral talocalcaneal (TC), talo1. metatarsal (T1M), talohorizontal (TH), and calcaneal inclination angle (CIA) that can be measured by x-rays. To increase the reliability of the findings, we also included the correlation between the lateral foot radiographs and the pedobarographic measurements within themselves in the study. As far as we know, there is no other comparison in the literature in adults with FSP complaints. In addition, another aim of this study is only x-ray, only clinical, only pedobarographic examination that is not conclusive and sometimes contradictory in making a diagnosis inpatient treatment. For this reason, this study, is to reveal this contradiction, if any, and to investigate the reliability of these examination methods. As a result, it is to prevent unnecessary examinations in diagnosis and to provide the right treatment, physiotherapy, and orthotics by reducing time, cost, and labor.

2. Materials and Methods

60 adult patients (39 women, 21 men) who applied to the Orthopedics and Traumatology Clinic of our hospital with the complaint of pain in the foot sole were retrospectively investigated. All radiological and pedobarographic examinations of the patients were performed in the clinic on the same day. The inclination criteria of the study was higher than 18 years, admitted to our hospital with foot pain, available weight-bearing lateral view foot radiograph, available pedobarographic measurement, pedobarographic measurement and radiological imaging performed on the same day, and able to stand and walk unsupported. Patients with standing congenital deformity, previous fracture history of the lower extremity, and neurological and metabolic diseases were excluded from our study. The demographic and foot pain characteristics of the patients were as shown in Table 2. In the literature, lateral foot radiographs have been used in the evaluation of MLA height (5,6,12,20-25). For this reason, we measured four different angles on the lateral weight-bearing foot radiographs (Figure 1). Lateral radiographs of the weight-bearing feet were evaluated by standardizing as described by Simons et al. (26). All angles were performed twice by the second author at different times, according to the methods described by Simons et al. (26) and Vanderwilde et al. (27). The values were recorded by taking the average of the two measurements.

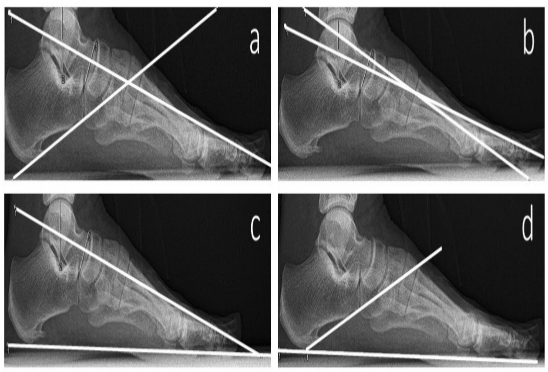

Figure 1. The Angles Measured on a Lateral Roentgenogram.

a: Talocalcaneal Angle, b: Talo-first Metatarsal Angle, c: Talohorizontal Angle, d: Calcaneal Inclination Angle

Lateral Talocalcaneal angle: It is the angle between the midpoint of the lines drawn from the neck and body of the talus and the lines drawn from the plantar edge of the calcaneus. While the value of this angle decreases with the varus and appendix angulation of the hind foot, it increases with heel valgus and pes calcaneus. Normal 25°-45°, PC<25°, PP>45° (28).

Talo-first metatarsal angle: It is the angle between the midpoint of the inclination angle formed by the lines drawn from the neck and body of the talus and the first metatarsal. While an increase is seen toward positive values in PP, values towards negative values are seen as the degree of deformity increases in PC. An angle that is greater than 4° convex downward is considered PP with an angle of 15°- 30° considered normal. An angle greater than 4 degrees convex upward is considered a PC (28).

Talo-horizontal angle: It is the angle between the inclination angle of the talus and the horizontal support surface. It gives information about the inclination of the talus. Normal 15°-25°, PC<15°, PP>25 (23).

Calcaneal inclination angle: It is the angle between the calcaneal inclination axis and the supporting horizontal surface. While decreasing in pes planus and it increases in PC. Normal 18°-20°, PC>20°, PP<18° (28).

The patient's foot sole pain was measured with a VAS of 10. It was graded by using a VAS pain Score ranging from 0 (no pain) to 10 (maximum pain).

Pedobarographic measurements were made by using a 6-meter-long pedobarography device (RsScan-Footscan® International Belgium, 40x100 cm, 8192 sensors, 253 Hz) embedded in the platform. The patient's height and weight were recorded before the measurements. Then, she/he was asked to step on the platform barefoot with both feet. In order to distribute the body weight equally on both feet and to provide the ideal step range, the patient was asked to step where she/he was. Afterward, the patient was told to look straight ahead and stand still with his hands on either side of her/his body. In this way, the static measured value was recorded. For dynamic measurement, the patient was asked to walk constantly at a comfortable walking speed, looking straight ahead. The measurement was terminated when both feet' soles were wholly seen on the screen 3 times. MLA height was evaluated in recorded static and dynamic pedobarographic measurements. A method similar to the AI method described by Cavanagh and Rodgers was used in the evaluation (29). The foot was divided into three plantar regions (fore, mid and hind feet) excluding the toes. The area covered by the midfoot was calculated with lines drawn from 50% and 69% of the total foot length measured from the toes to the heel (13). The AI value was found by dividing the midfoot area by the foot sole. (Figure 2). Matlab 2015 b Mathworks ® software was used to record and analyze the data. AI calculation was performed with this software. Normal 0.21-0.26, PC≤0.21, PP≥0.26 (13).

2.1. Statistical Analysis

The frequencies and percentages were given for categorical variables, and mean, standard deviation (SD), and range (minimum-maximum) values were given for numerical variables as descriptive statistics. Spearman correlation was used to investigate the linear relationship between numerical variables. The agreement of radiological and pedobarographic measurements among themselves and with each other was determined using the " Gwet AC1, Percent agreement (PA) and Cohen's / Conger's κ" coefficients of agreement (30,31). All agreement coefficients were presented with 95% confidence intervals (CI). Due to the problems associated with the Kappa coefficient (31), the Gwet AC1 coefficient, which gives more consistent and reliable results, was preferred, but according to the published guide (32), other two coefficients were also given in order to present more than one coefficient of agreement. The magnitudes of the agreement coefficients were interpreted according to the Landis and Koch benchmark scale (33). The benchmark interval to which an agreement coefficient belongs was determined with Gwet's probabilistic method.

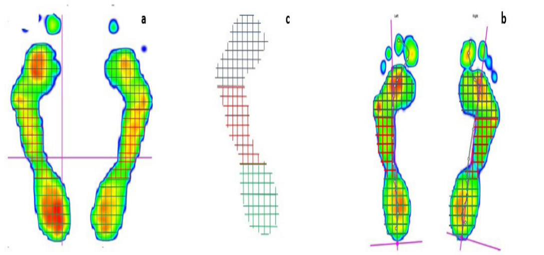

Figure 2. Arch Index Method Measurement with Matlab 2015 b MathWorks ® software

a; Static Arch Index, b; Dynamic Arch Index,

$$c;\ \text{Arch Index Method} = \frac{\text{Red Area}}{\text{Green Area} + \text{Red Area} + \text{Blue Area}}$$

Statistical significance was assessed at $p<0.05$ and all statistical analyses were performed using R software (R software, version 4.0.5, packages: arsenal-irrcac-ggplot2, R Foundation for Statistical Computing, Vienna, Austria; http://r project.org).

Ethical Aspect of the Research

The study's ethical approval was obtained from the relevant hospital (2018/05-38).

3. Results

In the study a total of 60 patients with foot pain were included, 65% of them were female and the patients' meanage was 45.32 ± 13.64. The mean height, weight, and body mass index of study the sample was 165.88 ± 8,08 he cm, 75.27 ± 15.31, and 27.61 ± 5.95 kg/m2. The mean FSP according to the VAS was 2.98±1.24 (Table 1).

Table 1. Demografic and Foot Pain Characteristics of The Patients (n=60)

	Mean (SD)	**Range**
Age (years)	45.32 (13.64)	18–69
Height (cm)	165.88 (8.08)	150–182
Weight (kg)	75.27 (15.31)	45–115
Body mass index (kg/m2)	27.61 (5.95)	16.65–46.06
Gender, Female: n (%)	39 (65.0)	
VAS	2,98 (1,24)	1-6

Abbreviation: VAS; Visual Analog Scale

The mean/median and range of the calcaneal pitch-angle, talocalcaneal angle, talohorizontal angle, talo-first metatarsal angle, static arch index, and dynamic arch index for both right and left feet were given in Table 2.

Table 2. Demografic and Foot Pain Characteristics of The Patients

(N=60)	Mean (SD)	Range
Age (years)	45.32 (13.64)	18–69
Height (cm)	165.88 (8.08)	150–182
Weight (kg)	75.27 (15.31)	45–115
Body mass index (kg/m2)	27.61 (5.95)	16.65–46.06
Gender, Female: n (%)	39 (65.0)	
VAS	2,98 (1,24)	1-6

Abbreviation: VAS; Visual Analog Scale

The relationships between radiological and pedobarographic measurements in the left (upper triangular) and right foot (lower triangular) were shown in Figure 3. The pattern of the colored correlation matrix was symmetric between the left and right foot as expected. Among the correlations of radiological measurements (4x4 part of the lower left corner of Figure 3 the weakest correlations, ranging from 0.022 to 0.156, were observed between TC and TM1, and TH. On the other hand, the strongest correlations were observed between TM1 and TH (Left: r=-0.792 and Right: r=-0.666, for both p<0.001) and TC and CIA (Left: r=0.575 and Right: r=0.675, for both p<0.001). Static and dynamic indices showed a strong positive correlation with each other (Left: r=0.800 and p<0.001, Right: r=0.825 and p<0.001). CIA showed the strongest correlations, not exceeding 0.546, with static and dynamic measurements among radiological measurements in both feet (Figure 3).

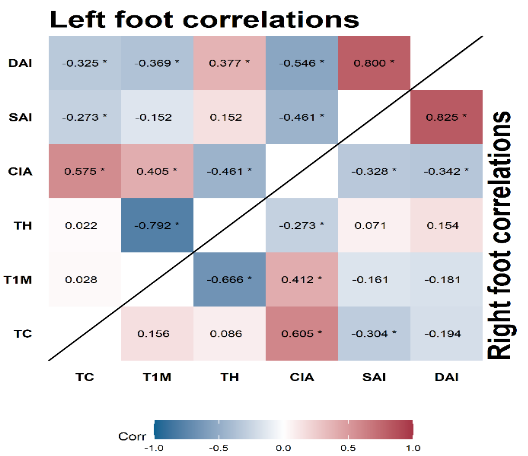

Figure 3. The Relationships Among Radiological, Pedobarographic Measurements and Demographic Data in Left (Upper Triangular) and Right Foot (Lower Triangular)

Abbreviations: DAI; Dynamic arch index, SAI; Static arch index, CIA; Calkaneal inclination angle, TH; Talo-horizontal angle,T1M; Talo-first metatarsal angle, TC; Talocalcaneal angle

Agreement among foot classifications of radiologic measurements was poor AC= -0.198 with 95% CI (-0.315,-0.080); PA = 0.167 with 95% CI (0.099,0.234) and k=-0.047 with 95% CI (-0.083,-0.01) considering all feet (n=120) (Table 3.1 and 3.2). While this agreement was moved one

Table 3.1. Agreement Between Radiologic Indicies and Pedobarographic Indicies

			Dynamic			Static			
			Normal	PP	PC	Normal	PP	PC	Total
			n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Left	TC								
		Normal	11 (84.6)	30 (90.9)	14 (100.0)	18 (100.0)	22 (88.0)	15 (88.2)	55 (91.7%)
		PP	2 (15.4)	2 (6.1)	0 (0.0)	0 (0.0)	2 (8.0)	2 (11.8)	4 (6.7%)
		PC	0 (0.0)	1 (3.0)	0 (0.0)	0 (0.0)	1 (4.0)	0 (0.0)	1 (1.7%)
	T1M								
		Normal	3 (23.1)	13 (39.4)	3 (21.4)	6 (33.3)	8 (32.0)	5 (29.4)	19 (31.7%)
		PP	10 (76.9)	20 (60.6)	11 (78.6)	12 (66.7)	17 (68.0)	12 (70.6)	41 (68.3%)
		PC	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0%)
	TH								
		Normal	7 (53.8)	27 (81.8)	3 (21.4)	10 (55.6)	18 (72.0)	9 (52.9)	37 (61.7%)
		PP	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0%)
		PC	6 (46.2)	6 (18.2)	11 (78.6)	8 (44.4)	7 (28.0)	8 (47.1)	23 (38.3%)
	CIA								
		Normal	4 (30.8)	5 (15.2)	1 (7.1)	3 (16.7)	5 (20.0)	2 (11.8)	10 (16.7%)
		PP	2 (15.4)	20 (60.6)	2 (14.3)	8 (44.4)	13 (52.0)	3 (17.6)	24 (40.0%)
		PC	7 (53.8)	8 (24.2)	11 (78.6)	7 (38.9)	7 (28.0)	12 (70.6)	26 (43.3%)
	Total		13 (21.7)	33 (55.0)	14 (23.3)	18 (30.0)	25 (41.7)	17 (28.3)	
Right	TC								
		Normal	18 (85.7)	24 (85.7)	8 (72.7)	15 (93.8)	24 (88.9)	11 (64.7)	50 (83.3%)
		PP	3 (14.3)	3 (10.7)	3 (27.3)	1 (6.2)	2 (7.4)	6 (35.3)	9 (15.0%)
		PC	0 (0.0)	1 (3.6)	0 (0.0)	0 (0.0)	1 (3.7)	0 (0.0)	1 (1.7%)
	T1M								
		Normal	9 (42.9)	14 (50.0)	4 (36.4)	7 (43.8)	13 (48.1)	7 (41.2)	27 (45.0%)
		PP	12 (57.1)	14 (50.0)	7 (63.6)	9 (56.2)	14 (51.9)	10 (58.8)	33 (55.0%)
		PC	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0%)
	TH								
		Normal	12 (57.1)	21 (75.0)	10 (90.9)	9 (56.2)	21 (77.8)	13 (76.5)	43 (71.7%)
		PP	1 (4.8)	0 (0.0)	0 (0.0)	1 (6.2)	0 (0.0)	0 (0.0)	1 (1.7%)
		PC	8 (38.1)	7 (25.0)	1 (9.1)	6 (37.5)	6 (22.2)	4 (23.5)	16 (26.7%)
	CIA								
		Normal	6 (28.6)	5 (17.9)	1 (9.1)	3 (18.8)	7 (25.9)	2 (11.8)	12 (20.0%)
		PP	5 (23.8)	9 (32.1)	1 (9.1)	7 (43.8)	7 (25.9)	1 (5.9)	15 (25.0%)
		PC	10 (47.6)	14 (50.0)	9 (81.8)	6 (37.5)	13 (48.1)	14 (82.4)	33 (55.0%)
	Total		21 (30.0)	28 (46.7)	11 (18.3)	16 (26.7)	27 (45.0)	17 (28.3)	

Abbreviations: TC; Talocalcaneal angle, T1M; Talo-first metatarsal angle, TH; Talo-horizontal angle, CIA; Calcaneal inclination angle, PP; Pes planus, PC; Pes cavus

Table 3.2. Coefficients of Agreement Between Radiologic Indicies and Pedobarographic Indicies

			Gwet's AC			Percent Agreement			Kappa		
			AC	95% CI*	Int.	PA	95% CI*	Int.	κ	95% CI*	Int.
Dynamic	Left	**TC**	-0.094	(-0.266,0.077)	Poor	0.217	(0.109,0.324)	Slight	-0.030	(-0.118,0.059)	Poor
		T1M	0.158	(-0.042,0.358)	Poor	0.383	(0.257,0.51)	Fair	-0.110	(-0.28,0.06)	Poor
		TH	-0.041	(-0.221,0.138)	Poor	0.300	(0.181,0.419)	Fair	0.099	(-0.021,0.219)	Slight
		CIA	**0.393**	(0.199,0.588)	Fair	**0.583**	(0.455,0.712)	Moderate	0.352	(0.171,0.532)	Fair
	Right	**TC**	0.107	(-0.089,0.302)	Poor	0.350	(0.226,0.474)	Fair	-0.023	(-0.146,0.099)	Poor
		T1M	**0.136**	(-0.053,0.324)	Poor	0.383	(0.257,0.51)	Fair	-0.053	(-0.251,0.146)	Poor
		TH	-0.124	(-0.306,0.057)	Poor	0.217	(0.109,0.324)	Slight	-0.131	(-0.249,-0.013)	Poor
		CIA	0.103	(-0.088,0.295)	Poor	**0.400**	(0.272,0.528)	Fair	0.158	(0.001,0.315)	Slight
Static	Left	**TC**	0.081	(-0.118,0.28)	Poor	0.333	(0.211,0.456)	Fair	0.037	(-0.026,0.1)	Poor
		T1M	0.130	(-0.068,0.328)	Poor	0.383	(0.257,0.51)	Fair	0.006	(-0.159,0.171)	Poor
		TH	-0.026	(-0.212,0.16)	Poor	0.300	(0.181,0.419)	Fair	0.009	(-0.133,0.151)	Poor
		CIA	**0.210**	(0.011,0.408)	Slight	**0.467**	(0.337,0.597)	Fair	0.193	(0.009,0.376)	Slight
	Right	**TC**	-0.013	(-0.206,0.18)	Poor	0.283	(0.166,0.401)	Slight	-0.016	(-0.099,0.067)	Poor
		T1M	0.070	(-0.123,0.263)	Poor	0.350	(0.226,0.474)	Fair	-0.028	(-0.197,0.142)	Poor
		TH	-0.142	(-0.313,0.028)	Poor	0.217	(0.109,0.324)	Slight	-0.079	(-0.208,0.05)	Poor
		CIA	**0.111**	(-0.085,0.308)	Poor	**0.400**	(0.272,0.528)	Fair	0.115	(-0.048,0.279)	Poor
	Left	**Static-Dynamic**	0.464	(0.273,0.654)	Fair	0.633	(0.508,0.759)	Moderate	0.427	(0.243,0.611)	Fair
		Among Radio.	0.018	(-0.082,0.118)	Poor	0.322	(0.267,0.377)	Fair	-0.094	(-0.141,-0.046)	Poor
	Right	**Static-Dynamic**	0.510	(0.324,0.695)	Fair	0.667	(0.544,0.789)	Moderate	0.483	(0.3,0.666)	Fair
		Among Radio.	0.122	(0.004,0.24)	Slight	0.383	(0.317,0.449)	Fair	-0.035	(-0.1,0.029)	Poor
	120 feet	**Static-Dynamic**	0.486	(0.355,0.617)	Fair	0.65	(0.563,0.737)	Moderate	0.453	(0.324,0.583)	Fair
		Among Radio.	-0.198	(-0.315,-0.08)	Poor	0.167	(0.099,0.234)	Slight	-0.047	(-0.083,-0.01)	Poor

Abbreviations: PA: percent agreement, CI*: Confidence interval, K: kappa, Int.:interpretation TC; Talocalcaneal angle, T1M; Talo-first metatarsal angle, TH; Talo-horizontal angle, CIA; Calkaneal inclination angle

degree higher on the right foot as "slight", the degree of the agreement remained the same on the left foot (as "poor") (Table 4.1 and 4.2). The agreement between static and dynamic classifications was fair AC=0.486 with 95% CI (0.355,0.617); PA =0.65 with 95% CI (0.563,0.737) and k=0.453 with 95% CI (0.324,0.583) considering 120 feet. When the agreement between radiologic and pedobarographic measurements was examined CIA showed the highest coefficients of agreement among other radiological measurements. However, the extent of an agreement reached a "fair" level only for the agreement with the dynamic measurement in the left foot (Table 3.1 and 3.2).

4.Discussion

The aim of this study was to determine the relationship between two methods that are frequently used in the measurement of MLA height in patients with FSP. In our study, all cases with a certain etiology that caused foot pain were excluded from the study. Only cases with idiopathic FSP were included in the study. The reason for this was to investigate the relationship between X-ray images and pedobarographic AI measurements objectively. We also included the relationship between lateral foot radiographs taken under weight-bearing and static and dynamic pedobarographic measurements in order to increase the reliability of these findings.

When we look at the correlation of the radiological measurements within themselves, we found a positive relationship between the TC and CIA angles and a negative relationship between the T1M and TH angles. While the inclination angle of the talus increases, the angle of the 1st metatarsal decreases. We think that this situation occurs due to the anatomical structure of the foot. Even in the study of Agoada et al. (5), they found the CIA and TC angle to be related but did not find a relationship between the CIA and TH angle. Radiological measurements are extremely important in terms of detecting bone pathologies in the foot. However, its two-dimensional nature and difficulties in the applicability of imaging standards create disadvantages (34). It is not possible to be sure that sufficient body weight is carried due to avoidance of pain in the imaging process performed when there is foot pain. This situation makes the use of images in the determination of MLA height controversial.

Table 4.1. Agreement Between Radiologic Indicies and Pedobarographic Indicies

			Dynamic			Static			
			Normal n (%)	**PP n (%)**	**PC n (%)**	**Normal n (%)**	**PP n (%)**	**PC n (%)**	**Total n (%)**
Left	**TC**								
		Normal	11 (84.6)	30 (90.9)	14 (100.0)	18 (100.0)	22 (88.0)	15 (88.2)	55 (91.7%)
		PP	2 (15.4)	2 (6.1)	0 (0.0)	0 (0.0)	2 (8.0)	2 (11.8)	4 (6.7%)
		PC	0 (0.0)	1 (3.0)	0 (0.0)	0 (0.0)	1 (4.0)	0 (0.0)	1 (1.7%)
	T1M								
		Normal	3 (23.1)	13 (39.4)	3 (21.4)	6 (33.3)	8 (32.0)	5 (29.4)	19 (31.7%)
		PP	10 (76.9)	20 (60.6)	11 (78.6)	12 (66.7)	17 (68.0)	12 (70.6)	41 (68.3%)
		PC	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0%)
	TH								
		Normal	7 (53.8)	27 (81.8)	3 (21.4)	10 (55.6)	18 (72.0)	9 (52.9)	37 (61.7%)
		PP	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0%)
		PC	6 (46.2)	6 (18.2)	11 (78.6)	8 (44.4)	7 (28.0)	8 (47.1)	23 (38.3%)
	CIA								
		Normal	4 (30.8)	5 (15.2)	1 (7.1)	3 (16.7)	5 (20.0)	2 (11.8)	10 (16.7%)
		PP	2 (15.4)	20 (60.6)	2 (14.3)	8 (44.4)	13 (52.0)	3 (17.6)	24 (40.0%)
		PC	7 (53.8)	8 (24.2)	11 (78.6)	7 (38.9)	7 (28.0)	12 (70.6)	26 (43.3%)
	Total		13 (21.7)	33 (55.0)	14 (23.3)	18 (30.0)	25 (41.7)	17 (28.3)	
Right	**TC**								
		Normal	18 (85.7)	24 (85.7)	8 (72.7)	15 (93.8)	24 (88.9)	11 (64.7)	50 (83.3%)
		PP	3 (14.3)	3 (10.7)	3 (27.3)	1 (6.2)	2 (7.4)	6 (35.3)	9 (15.0%)
		PC	0 (0.0)	1 (3.6)	0 (0.0)	0 (0.0)	1 (3.7)	0 (0.0)	1 (1.7%)
	T1M								
		Normal	9 (42.9)	14 (50.0)	4 (36.4)	7 (43.8)	13 (48.1)	7 (41.2)	27 (45.0%)
		PP	12 (57.1)	14 (50.0)	7 (63.6)	9 (56.2)	14 (51.9)	10 (58.8)	33 (55.0%)
		PC	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0%)
	TH								
		Normal	12 (57.1)	21 (75.0)	10 (90.9)	9 (56.2)	21 (77.8)	13 (76.5)	43 (71.7%)
		PP	1 (4.8)	0 (0.0)	0 (0.0)	1 (6.2)	0 (0.0)	0 (0.0)	1 (1.7%)
		PC	8 (38.1)	7 (25.0)	1 (9.1)	6 (37.5)	6 (22.2)	4 (23.5)	16 (26.7%)
	CIA								
		Normal	6 (28.6)	5 (17.9)	1 (9.1)	3 (18.8)	7 (25.9)	2 (11.8)	12 (20.0%)
		PP	5 (23.8)	9 (32.1)	1 (9.1)	7 (43.8)	7 (25.9)	1 (5.9)	15 (25.0%)
		PC	10 (47.6)	14 (50.0)	9 (81.8)	6 (37.5)	13 (48.1)	14 (82.4)	33 (55.0%)
	Total		21 (30.0)	28 (46.7)	11 (18.3)	16 (26.7)	27 (45.0)	17 (28.3)	

Abbreviations: TC; Talocalcaneal angle, T1M; Talo-first metatarsal angle, TH; Talo-horizontal angle, CIA; Calkaneal inclination angle, PP; Pes planus, PC; Pes cavus

In the static and dynamic pedobarographic analysis, we found that the AI value was poorly correlated with only CIA. In their study, Yalçın et al. (20) found CIA incompatible with AI. Kanatli et al. (24) found a correlation between AI and T1M and TH. Cavanagh et al. (29) found that the navicular height and AI in radiological measurements were 50% compatible. Agoada et al. (5) also stated that CIA should be used for MLA height determination in radiological measurements. We also agree with this view. Although the talus is an important bone in the foot structure, it cannot be effective in determining the height of the MLA. Because of the lack of talus muscle, it determines its position relative to the calcaneus and navicular bone. The positions of the calcaneus and navicular bone during walking and standing give direction to the movement of the talus. In fact, while the talus transfers body weight to other muscle and bone

Table 4.2. Coefficients of Agreement Between Radiologic Indicies and Pedobarographic Indicies

			Gwet's AC			Percent Agreement			Kappa		
			AC	95% CI*	Int.	PA	95% CI*	Int.	κ	95% CI*	Int.
Dynamic	Left	TC	-0.094	(-0.266,0.077)	Poor	0.217	(0.109,0.324)	Slight	-0.030	(-0.118,0.059)	Poor
		T1M	0.158	(-0.042,0.358)	Poor	0.383	(0.257,0.51)	Fair	-0.110	(-0.28,0.06)	Poor
		TH	-0.041	(-0.221,0.138)	Poor	0.300	(0.181,0.419)	Fair	0.099	(-0.021,0.219)	Slight
		CIA	**0.393**	(0.199,0.588)	Fair	**0.583**	(0.455,0.712)	Moderate	0.352	(0.171,0.532)	Fair
	Right	TC	0.107	(-0.089,0.302)	Poor	0.350	(0.226,0.474)	Fair	-0.023	(-0.146,0.099)	Poor
		T1M	**0.136**	(-0.053,0.324)	Poor	0.383	(0.257,0.51)	Fair	-0.053	(-0.251,0.146)	Poor
		TH	-0.124	(-0.306,0.057)	Poor	0.217	(0.109,0.324)	Slight	-0.131	(-0.249,-0.013)	Poor
		CIA	0.103	(-0.088,0.295)	Poor	**0.400**	(0.272,0.528)	Fair	**0.158**	(0.001,0.315)	Slight
Static	Left	TC	0.081	(-0.118,0.28)	Poor	0.333	(0.211,0.456)	Fair	0.037	(-0.026,0.1)	Poor
		T1M	0.130	(-0.068,0.328)	Poor	0.383	(0.257,0.51)	Fair	0.006	(-0.159,0.171)	Poor
		TH	-0.026	(-0.212,0.16)	Poor	0.300	(0.181,0.419)	Fair	0.009	(-0.133,0.151)	Poor
		CIA	**0.210**	(0.011,0.408)	Slight	**0.467**	(0.337,0.597)	Fair	0.193	(0.009,0.376)	Slight
	Right	TC	-0.013	(-0.206,0.18)	Poor	0.283	(0.166,0.401)	Slight	-0.016	(-0.099,0.067)	Poor
		T1M	0.070	(-0.123,0.263)	Poor	0.350	(0.226,0.474)	Fair	-0.028	(-0.197,0.142)	Poor
		TH	-0.142	(-0.313,0.028)	Poor	0.217	(0.109,0.324)	Slight	-0.079	(-0.208,0.05)	Poor
		CIA	**0.111**	(-0.085,0.308)	Poor	**0.400**	(0.272,0.528)	Fair	**0.115**	(-0.048,0.279)	Poor
	Left	Static-Dynamic	0.464	(0.273,0.654)	Fair	0.633	(0.508,0.759)	Moderate	0.427	(0.243,0.611)	Fair
		Among Radio.	0.018	(-0.082,0.118)	Poor	0.322	(0.267,0.377)	Fair	-0.094	(-0.141,-0.046)	Poor
	Right	Static-Dynamic	0.510	(0.324,0.695)	Fair	0.667	(0.544,0.789)	Moderate	0.483	(0.3,0.666)	Fair
		Among Radio.	0.122	(0.004,0.24)	Slight	0.383	(0.317,0.449)	Fair	-0.035	(-0.1,0.029)	Poor
	120 feet	Static-Dynamic	0.486	(0.355,0.617)	Fair	0.65	(0.563,0.737)	Moderate	0.453	(0.324,0.583)	Fair
		Among Radio.	-0.198	(-0.315,-0.08)	Poor	0.167	(0.099,0.234)	Slight	-0.047	(-0.083,-0.01)	Poor

Abbreviations: PA: percent agreement, CI*: Confidence interval, K: kappa, Int.:interpretation TC; Talocalcaneal angle, T1M; Talo-first metatarsal angle, TH; Talo-horizontal angle, CIA; Calkaneal inclination angle

structures, it transfers the ground reaction force to the upper segments to be absorbed in the opposite direction. Therefore, though it is an important bone in the foot structure, its importance in terms of functionality are less.

Another reason for us to think that the use of the talus in radiological measurements to determine the MLA height will lead to a mistake is its two-dimensional evaluation. The accurate evaluation of the talus can only be possible with three-dimensional images. The decrease in MLA height during walking and standing increases the pressure area in the foot. It also causes the pronation center of gravity in the talus to be transferred to the medial aspect of the foot. This situation is realized by the movement behavior of the Subtalar joint (STJ).

The position of the STJ in pedobarography can only be possible by determining the foot pressure area. The reason for the high correlation between static and dynamic measurements is to ensure equal full-weight bearing feet during static imaging. However, this may not be possible in radiological imaging. For this reason, STJ evaluation can be achieved with pedobarographic static measurement, not as much as dynamic evaluation though.

In dynamic images, all of the body weight is carried on the feet. In this way, the effects of the ground reaction force in walking on foot can be fully and truly evaluated.

5. Conclusion and Recommendations

As a result, pedobarographic measurements are non-invasive, easy, inexpensive, and have no radiation exposure. It will be the gold standard in the future due to its dynamic evaluation of the foot.

In addition to all these, the level of pain during the imaging should be evaluated very well. Since high pain will cause an antalgic gait, it will cause errors in the measurements. It should also be kept in mind that the experience and knowledge of the person making the measurements will also be an important factor. AI findings of MLA in pedobarography are consistent with CIA that is measured radiographically. In the absence of pedobarography, the CIA may provide insight into the arch. If the static evaluation of pedobarography is realized in accordance with the standards, it can provide the correct evaluation. Number of the patients should be increased in future studies. Pedobarography should be compared with dynamic x-ray. In painful feet, the degree of pain between both feet should be evaluated and foot dominance should be taken into consideration.

6. Contribution to the Field

Our study can give clinicians an idea that pedobarographic measurement, a non-invasive, inexpensive, and fast method, is a reliable method for diagnosing foot pain.

Acknowledgments

The authors thank Semiha Özgül for the statistical analysis and production of all tables and figures 3, the authors thank Anıl Murat Öztürk for figures 1 and 2 also the authors thank Özgür Koska for Madlab analyzes.

Competing interests

The authors report no conflicts of interest.

Funding

No funding was received

Author Contribution

Idea/Concept: DB, SN, MHÖ; **Design:** DB, SN, MHÖ; **Control/Supervision:** DB, SN, MHÖ; **Sources and Funding:** DB, SN, MHÖ; **Materials:** DB, SN, MHÖ; **Data Collection and/or Processing:** DB, SN, MHÖ; **Analysis and/or Interpretation:** DB, SN, MHÖ; **Literature Review:** DB, SN, MHÖ; **Writing the Article:** DB, SN, MHÖ; **Critical Review:** DB, SN, MHÖ.

References

1. Gates LS, Arden NK, Hannan MT, Roddy E, Gill TK, Hill CL, Dufour AB, et al. Prevalence of foot pain across an International Consortium of Population-Based cohorts. Arthritis Care Res (Hoboken) [Internet]. 2019 [cited 2022 Jan 2];71(5):661-70. Available from: https://doi.org/10.1002/acr.23829

2. Zuil-Escobar JC, Martínez-Cepa CB, Martín-Urrialde JA, Gómez-Conesa A. Medial longitudinal arch: Accuracy, reliability, and correlation between navicular drop test and footprint parameters. J Manipulative Physiol Ther [Internet]. 2018 [cited 2022 Jan 2];41(8):672-9. Available from: https://doi.org/10.1016/j.jmpt.2018.04.001

3. Vazquez-Zorrilla D, Millan-Alanis JM, Alvarez-Villalobos NA, Elizondo-Omaña RE, Guzman-Lopez S, Vilchez-Cavazos JF, Fernandez-Rodarte BA, Quiroga-Garza A et al. Anatomy of foot Compartments: a systematic review. Ann Anat - Anat Anzeiger [Internet]. 2020 [cited 2022 Jan 2];229(May 2020):1-8. Available from: https://pubmed.ncbi.nlm.nih.gov/31978573/

4. Morton DJ. The human foot: Its evolutionary development, physiology and functional disorders. New York: Columbia University Press; 1935. 696 p.

5. Agoada D, Kramer PA. Radiographic measurements of the talus and calcaneus in the adult pes planus foot type. Am J Phys Anthropol [Internet]. 2020 [cited 2022 May 21]; 171(4):613-627. Available from: https://onlinelibrary.wiley.com/doi/full/10.1002/ajpa.

6. Williams DS, McClay IS. Measurements Used to Characterize the Foot and the Medial Longitudinal Arch: Reliability and Validity. Phys Ther [Internet]. 2000 [cited 2022 Jan 2];80(9):864-871. Available from: https://academic.oup.com/ptj/article/80/9/864/2842502?login=true

7. Granado M. Pes cavus. Cinahl Information Systems [Internet]. 2021 [cited 2022 Jan 2];1-13. Available from: https://www.ebsco.com/sites/g/files/nabnos191/files/acquiadam-assets/Rehabilitation-Reference-Center-Clinical-Review-Pes-Cavus.pdf

8. Fernández-Seguín LM, Diaz Mancha JA, Sánchez Rodríguez R, Escamilla Martínez E, Gómez Martín B, Ramos Ortega J. Comparison of plantar pressures and contact area between normal and cavus foot. Gait Posture [Internet]. 2014 [cited 2022 Jun 1]; 39(2):789-792. Available from: https://www.sciencedirect.com/science/article/pii/S0966636213006528

9. Yeagerman SE, Cross MB, Positano R, Positano R. Evaluation and treatment of symptomatic pes planus. Curr Opin Pediatr [Internet]. 2011[cited 2022 Jan 5];23(1):60-7. Available from: https://doi.org/10.1097/MOP.0b013e32834230b2

10. Sanpera I, Villafranca-Solano S, Muñoz-Lopez C, Sanpera-Iglesias J. How to manage pes cavus in children and adolescents? EFORT Open Rev [Internet]. 2021 [cited 2023 Jul 4]; 6(6):510-517. Available from: https://pubmed.ncbi.nlm.nih.gov/34267941/

11. Salinas-Torres VM, Salinas-Torres RA, Carranza-García LE, Herrera-Orozco J, Tristán-Rodríguez JL. Prevalence and Clinical Factors Associated With Pes Planus Among Children and Adults: A Population-Based Synthesis and Systematic Review. J Foot Ankle Surg [Internet]. 2023[cited 2023 Jul 4]; 000:1-5. Available from: https://pubmed.ncbi.nlm.nih.gov/37286098/

12. Xiong S, Goonetilleke RS, Witana CP, Weerasinghe TW, Lee AU EY. Foot arch characterization. J Am Podiatr Med Assoc [Internet]. 2010 [cited 2022 Jan 2];100(1):14-24. Available from: https://pubmed.ncbi.nlm.nih.gov/20093541/

13. Kanatli U, Yetkin H, Bolukbasi S. Evaluation of the transverse metatarsal arch of the foot with gait analysis. Arch Orthop Trauma Surg [Internet]. 2003 [cited 2018 May 2];123(4):148-50. Available from: https://doi.org/10.1007/s00402-002-0459-7

14. Carrara C, Caravaggi P, Belvedere C, Leardini A. Radiographic angular measurements of the foot and ankle in weight-bearing: A literature review. Foot Ankle Surg [Internet]. 2020 [cited 2022 Jan 2];26(5):509-17. Available from: https://doi.org/10.1016/j.fas.2019.07.008

15. Ludlow JB. Hand-wrist, knee, and foot-ankle dosimetry and image quality measurements of a novel extremity imaging unit providing CBCT and 2D imaging options. Med Phys [Internet]. 2018 [cited 2022 Jan 3];45(11):4955-63. Available from: https://doi.org/10.1002/mp.13198

16. Schepers T, Van der Stoep A, Van der Avert H, Esther MM, Leishout V, Patka P. Plantar pressure analysis after percutaneous repair of displaced intra-articular calcaneal fractures. Foot Ankle Int [Internet]. 2008 [cited 2022 Jan 3];29(2):128-35. Available from: https://doi.org/10.3113/FAI.2008.0128

17. Hee HT, Lee EH, Lee GS. Gait and pedobarographic patterns of surgically treated clubfeet. J Foot Ankle Surg [Internet]. 2001 [cited 2022 Jan 9];40(5):287-94. Available from: https://doi.org/10.1016/S1067-2516(01)80064-8

18. Skopljak A, Muftic M, Sukalo A, Masic I. Pedobarography in Diagnosis and Clinical Application. Acta Inform Medica [Internet]. 2014 [cited 2022 Jan 4]; 22(6):374. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4315649/

19. Onodera AN, Sacco ICN, Morioka EH, Souza PS, Sá MR de, Amadio AC. What is the best method for child longitudinal plantar arch assessment and when does arch maturation occur? Foot [Internet]. 2008 [cited 2022 Jan 4]; 18(3):142-149. Available from: https://www.sciencedirect.com/science/article/pii/S0958259208000308

20. Yalçin N. Evaluation of the medial longitudinal arch: a comparison between the dynamic plantar pressure measurement system and radiographic analysis. Acta Orthop Traumatol Turc [Internet]. 2010 [cited 2018 May 2];44(3):241-5. Available from: https://doi.

org/10.3944/AOTT.2010.2233

21. Subotnick SL. The Biomechanics of Running Implications for the Prevention of Foot Injuries. Sport Med [Internet]. 1985 [cited 2018 May 1];2(2):144-53. Available from: https://pubmed.ncbi.nlm.nih.gov/2860714/

22. Saltzman CL, Nawoczenski DA, Talbot KD. Measurement of the medial longitudinal arch. Arch Phys Med Rehabil [Internet]. 1995 [cited 2018 May 2];76(1):45-9. Available from: https://doi.org/10.1016/S0003-9993(95)80041-7

23. Deforth M, Zwicky L, Horn T, Hintermann B. The effect of foot type on the Achilles tendon moment arm and biomechanics. Foot [Internet]. 2019 [cited 2022 Jan 2];38:91-4. Available from: https://doi.org/10.1016/j.foot.2018.10.003

24. Kanatli U, Yetkin H, Cila E. Footprint and radiographic analysis of the feet. J Pediatr Orthop [Internet]. 2001 [cited 2018 May 1];21(2):225-8. Available from: https://doi.org/10.1097/01241398-200103000-00018

25. Naseer S, Babu R, Panjala A, Arifuddin MS, Manfusa H, Rao EV. Comparison of medial longitudinal arches of the foot by radiographic method in users and nonusers of high-heeled footwear among young women. J Anat Soc India [Internet]. 2021 [cited 2022 Jan 4];70(4):226-32. Available from: https://doi.org/10.4103/jasi.jasi_202_20

26. Simons GW. A standardized method for the radiographic evaluation of clubfeet. Clin Orthop Relat Res [Internet]. 1978 [cited 2022 Jan 6];135:107-18. Available from: https://doi.org/10.1097/00003086-197809000-00025

27. Vanderwilde R, Staheli LT, Chew DE M V. Measurements on radiographs of the foot in normal infants and children. J Bone Joint Surg Am [Internet]. 1988 [cited 2022 Jan 6 ;70(3):407-15. Available from: https://pubmed.ncbi.nlm.nih.gov/3346265/

28. Wadee AN. Influence of wearing high heel on different foot angels in normal female subjects. Med J Cairo Univ [Internet]. 2017 [cited 2022 Jan 13];85(811):1-13.Available from: https://scholar.cu.edu.eg/sites/default/files/anazih/files/6_nskh_lbhth_lrl.pdf

29. Cavanagh PR, Rodgers MM. The arch index: A useful measure from footprints. J Biomech [Internet]. 1987 [cited 2018 May 1];20(5):547-51. Available from: https://doi.org/10.1016/0021-9290(87)90255-7

30. Gwet KL. Handbook of inter-rater reliability. 4th ed. Gaithersburg, United States of America: Advanced Analytics LLC; 2014. 104 p.

31. Kottner J, Audige L, Brorson S, Donner A, Gajewski BJ, Hróbjartsson, et al. Guidelines for eporting reliability and agreement studies (GRRAS) were proposed. Int J Nurs Stud [Internet]. 2011 [cited 2018 Jun 1];48(6):661-71. Available from: https://doi.org/10.1016/j.ijnurstu.2011.01.016

32. Feinstein AR, Cicchetti D V. High agreement but low Kappa: I. the problems of two paradoxes. J Clin Epidemiol [Internet]. 1990 [cited 2018 Jun 1];43(6):543-9. Available from: https://doi.org/10.1016/0895-4356(90)90158-L

33. Conger AJ. Integration and generalization of kappas for multiple raters. Psychol Bull [Internet]. 1980 [cited 2018 Jun 1]; 88(2):322-8. Available from: https://psycnet.apa.org/record/1980-29309-001

34. Woei Chyn Chu, Shin Hwa Lee, Chu W, Tzyy-Jiuan Wang, Maw-Chang Lee. The use of arch index to characterize arch height: a digital image processing approach. IEEE Trans Biomed Eng [Internet]. 1995[cited 2018 Jun 5];42(11):1088-1093. Available from: https://ieeexplore.ieee.org/document/469375