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Relationship of Calcaneal Angles with Age, Sex, Side, Height and Body Weight

Relación de los Ángulos Calcáneos con la Edad, el Sexo, la Lateralidad, la Altura y el Peso Corporal

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SUMMARY: This study aims to investigate the relationships between Böhler (BA), Gissane (GA), calcaneal inclination (CIA), lateral talocalcaneal (LTCA), and Fowler-Philip (FPA) angles, which play a significant role in the diagnosis of foot deformities and in clinical and surgical decision-making, and age, sex, laterality, body height, and body weight. Additionally, this study aims to establish individual-specific normative reference values. Bilateral weight-bearing lateral foot radiographs (n=850) of 425 individuals (216 males, 209 females; mean age: 45.14 ± 15.82 years) without foot pathology were analyzed. The mean values were BA:30.59 ± 3.5°, GA:116.06 ± 4.64°, CIA:25.5 ± 3.62°, LTCA:44.14 ± 6.87°, and FPA:61.44 ± 2.73°. There were significant differences compared to measurements reported in other populations. BA, CIA, LTCA, and FPA demonstrated significant differences across age groups (BA: p=0.002; CIA: p<0.001; LTCA: p<0.001; FPA: p<0.001). GA and FPA exhibited significant sex-related differences (GA: p=0.011; FPA: p<0.001). No significant correlation was determined between the angles and side. In males, BA was correlated with height positively (r=0.185, p<0.001), while GA showed a positive correlation (r=0.148, p=0.003) and CIA a negative correlation (r=-0.141, p=0.004) with height in females. Regarding body weight, BA was positively correlated in males (r=0.139, p=0.004), whereas CIA (r=-0.156, p=0.001) and LTCA (r=-0.137, p=0.004) showed negative correlations. In females, LTCA was also correlated with weight negatively (r=-0.193, p<0.001). Given the regression analysis, age was associated with a 0.025° decrease in BA per year (p=0.001). GA was, on average, 1.854° higher in females than in males (p<0.001). Each 1 cm increase in height was related with a 0.075° increase in GA (p=0.001), while each 1 kg increase in body weight was related with decreases of 0.051° in CIA (p<0.001), 0.104° in LTCA (p<0.001), and 0.019° in FPA (p=0.024). These findings highlight the necessity of considering age, sex, height, and body weight in addition to population-based reference values when evaluating calcaneal angles.

KEY WORDS: Calcaneus; Angles; Age factors; Height; Body weight.

INTRODUCTION

Angular measurements of the calcaneus are critical parameters that are assessed through planar radiographs and guide clinical decision-making (Thomas *et al*., 2006). These angles are widely utilized not only in analyses of lower limb biomechanics and postural balance but also in the diagnosis, surgical planning, and prognosis of conditions such as calcaneal fractures, pes planus, pes cavus, pes equinovarus, Haglund deformity, and metatarsus varus (Dahiru *et al*., 2013; Ramachandran & Shetty, 2015; Tourné *et al*., 2018).

Böhler's angle (BA), first described in 1931 by Dr. Lorenz Böhler, is an obtuse angle formed by the intersection of two lines on a lateral radiograph of the calcaneus and it is also known as the tuber-joint angle (TJA) (Seyahi *et al*., 2009; Shoukry *et al*., 2012). Böhler proposed a normal range of 30°-35° and associated reductions in this angle with posterior facet fractures (Böhler, 1931). Previous studies reported normal ranges of BA to be 21.1°-47.3°, 22°-40°, 20°-50°, 16°-47°, and 25.1°-49.5° (Igbigbi & Mutesasira, 2003; Khoshhal *et al*., 2004; Thomas et. al., 2006; Shoukry *et al*., 2012; Zivanovic-Macuzic *et al*., 2018).

Gissane's angle (GA), described in 1947 by Dr. William Gissane, is the broad angle formed by two cortical lines beneath the lateral process of the talus (Gissane, 1947). Referred to as "the crucial angle of Gissane," normal range of GA was reported to be 87.5°-137.8°, 108°-138°, and 96°-152° in the literature (Khoshhal *et al*., 2004; Shoukry *et al*.,

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2012; Ramachandran & Shetty, 2015) A GA below these thresholds because of subtalar joint structure being deteriorated due to axial compression indicates a calcaneal fracture (Seyahi *et al*., 2009; Shoukry *et al*., 2012).

The calcaneal inclination angle (CIA), also known as the calcaneal pitch angle, indicates the inclination of the calcaneus relative to the ground and correlates with the height of the medial longitudinal arch of the foot (Gissane, 1947; Shibuya *et al*., 2012). Normal ranges of this angle, which is also referred to as calcaneal pitch angle, were reported to be 5.2°-43.3° and 12°-33° in the literature. A decreased CIA is observed in pes planus and calcaneal fractures, whereas an increased angle is associated with pes cavus and Haglund deformity (Gentili *et al*., 1996; Schepers *et al*., 2007).

The lateral talocalcaneal angle (LTCA), defined by the angle between the longitudinal axes of the talus and calcaneus, and is an important metric in foot biomechanics (Dahiru *et al*., 2013). Normative ranges in the literature include 25.5°-68.2°, 32°-58°, and 18°-56° (Thomas *et al*., 2003; Schepers *et al*., 2007; Dahiru *et al*., 2013). LTCA tends to increase in pes planus and metatarsus varus, whereas it decreases in pes equinovarus and congenital vertical talus (Shoukry *et al*., 2012).

The Fowler-Philip angle (FPA), introduced by Fowler and Philip in 1945, is considered a distinguishing radiologic parameter in the evaluation of symptomatic Haglund deformities (Fowler & Philip, 1945). While Fowler and Philip reported the normal range to be 44°-69°, they also noted that angles ≥75° may be associated with retrocalcaneal bursitis or Haglund deformity (Fowler & Philip, 1945; Tourné *et al*., 2018). There also are studies reporting normal ranges to be 36°-69.5° (Tourné *et al*., 2018).

Previous studies primarily focused on population-specific measurements and inter-population differences in calcaneal angles (Thomas *et al*., 2003; Khoshhal *et al*., 2004; Schepers *et al*., 2007; Kang *et al*., 2012; Shibuya *et al*., 2012; Shoukry *et al*., 2012; Dahiru *et al*., 2013; Igbigbi & Mutesasira, 2013; Ramachandran & Shetty, 2015; Tourné *et al*., 2018; Zivanovic-Macuzic *et al*., 2018; Da Silva Louro *et al*., 2020). However, examining the previous studies, there is a gap regarding the associations between these angles and factors such as age, sex, side, height, and body weight.

This study aims to evaluate the relationships between BA, CA, CIA, LTCA, and FPA measured on radiographs of individuals without any foot pathology and age, sex, side, height, and body weight using linear regression analyses, as week as establishing individual-specific normative reference values for these angles.

MATERIAL AND METHOD

In this retrospective study, a total of 850 lateral weight-bearing foot radiographs (425 right, 425 left) belonging to 425 patients (216 males, 209 females; mean age: 45.14 ± 15.82 years) aged between 18 and 87 years were evaluated. All patients had bilateral weight-bearing lateral foot radiographs and had no fractures or deformities in the calcaneus or other foot bones, no history of rheumatologic disease, and no prior foot or ankle surgery. Ethics committee approval was obtained for the study (GOKA EK 2024/16/16).

To analyze the relationship between angular measurements and age, patients were categorized by decade. Body height (mean: 166.72 ± 8.99 cm) and body weight (mean: 71.01 ± 11.68 kg) data were retrieved from hospital records.

Radiographs in DICOM format were imported into ImageJ software (v1.48, NIH, USA). Digital measurements of BA, GA, CIA, LTCA, and FPA were performed by three independent observers (EA, AU, OB) based on predefined reference lines. The mean value of the three observers was used for each angle. Measurements with discrepancies exceeding 5° were excluded from analysis.

BA was measured as the angle between a line connecting the highest point of the posterior facet and the highest point of the anterior process of the calcaneus, and a second line connecting the highest point of the posterior facet to the highest point of the calcaneal tuberosity (Fig. 1) (Böhler, 1931; Thomas *et al*., 2003; Seyahi *et al*., 2009; Shoukry *et al*., 2012).

GA is the angle formed between a line drawn from the lowest to the highest point of the posterior facet and a line drawn from the lowest point of the posterior facet to the highest point on the anterior surface (Fig. 1) (Gissane, 1947; Shibuya *et al*., 2012).

CIA was defined as the angle between a tangent line drawn along the inferior surface of the calcaneus and the horizontal weight-bearing surface of the foot (Fig. 1) (Thomas *et al*, 2003.; Shibuya *et al*., 2012).

LTCA was measured as the angle between the longitudinal axes of the talus and the calcaneus, representing the inclination of the talus over the calcaneus (Fig. 1) (Schepers *et al*., 2007; Dahiru *et al*., 2013).

FPA is the angle between a line parallel to the plantar surface of the calcaneus and a tangent line passing through the posterior aspect of the calcaneal tuberosity (Fig. 1) (Fowler & Philip, 1945; Tourné *et al*., 2018).

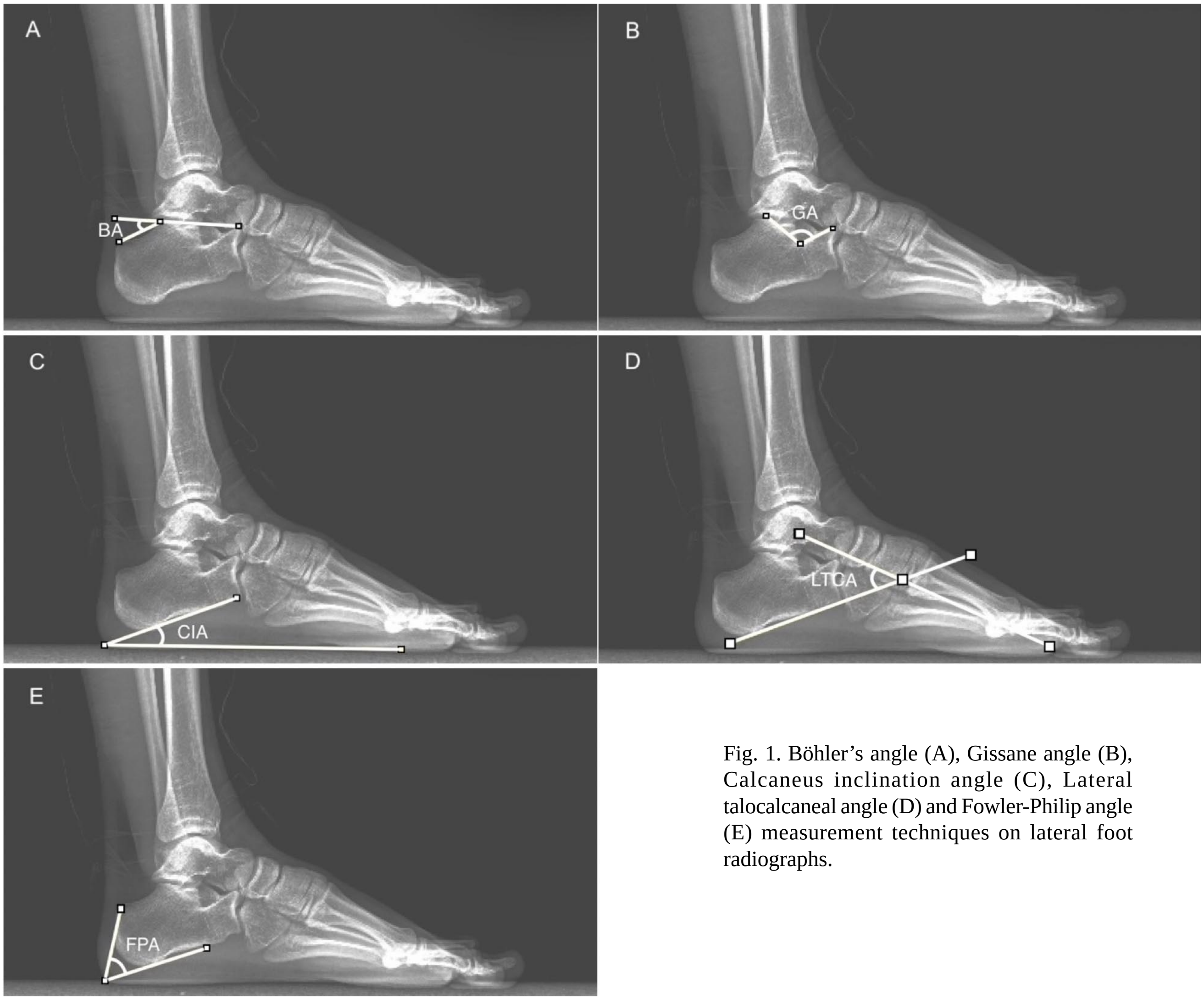

Fig. 1. Böhler's angle (A), Gissane angle (B), Calcaneus inclination angle (C), Lateral talocalcaneal angle (D) and Fowler-Philip angle (E) measurement techniques on lateral foot radiographs.

Data were analyzed using IBM SPSS v23.0 (Armonk, NY, USA). Normality was tested employing the Kolmogorov-Smirnov test and skewness-kurtosis coefficients. For non-normally distributed angular values, comparisons by side and sex were made using the Mann-Whitney U test, and comparisons by age group were made using the Kruskal-Wallis test. Post hoc comparisons were conducted employing the Dunn test. Comparisons with values reported in the literature were conducted using the Runs test.Relationships between angles and non-normally distributed height and weight values were analyzed using Spearman's rho correlation coefficient. Factors affecting angular values were examined via linear regression analysis. Results were presented as mean ± SD and median (min-max). Statistical significance was set at $p<0.05$.

RESULTS

The mean BA was found to be 30.59 ± 3.5°. No significant differences in BA were observed between sides ($p = 0.945$) or sexes ($p = 0.846$); however, significant differences were observed among age groups ($p = 0.002$), with the highest values noted in the 18–29 age group. The mean GA was 116.06 ± 4.64°. A significant difference was observed between sexes ($p = 0.011$), with males having lower values. GA did not differ significantly by age group ($p = 0.184$) or side ($p = 0.974$). The mean CIA was 25.5 ± 3.62°. Although no significant differences were found by side ($p = 0.887$) or sex ($p = 0.053$), a significant difference was determined among age groups ($p<0.001$), with the highest values observed in individuals aged 70 and older (27.49 ± 3.14). The mean LTCA was 44.14 ± 6.87°. There was no significant difference in LTCA values between sides ($p = 0.928$) or sexes (p = 0.858). However, significant differences were observed across age groups (p<0.001), with the highest mean LTCA recorded in individuals aged 70 and older (48.78 ± 4.55°). The mean FPA was 61.44 ± 2.73°. FPA did not differ by side (p = 0.974) but showed significant differences between sexes (p<0.001) and among age groups (p<0.001). The highest mean FPA was recorded in the 7th decade (62.21 ± 2.53°). Table I summarizes the distribution of calcaneal angle measurements according to side, sex, and age group.

Table I. Comparison of calcaneal angles by side, sex, and age group.

		BA	GA	CIA	LTCA	FPA
	n(%)	Mean±SD Median (min-max)	Mean±SD Median (min-max)	Mean±SD Median (min-max)	Mean±SD Median (min-max)	Mean±SD Median (min-max)
	850(100)	30.59 ± 3.5 30,42 (21,13 - 39,98)	116.06 ± 4.64 116,39 (102,69 - 132,88)	25.5 ± 3.62 25,55 (15,78 - 36,74)	44.14 ± 6.87 44,09 (26,54 - 66,34)	61.44 ± 2.73 61,02 (52,3 - 76,65)
Side						
Right	425(50)	30.6 ± 3.53 30.43 (21.13 - 39.56)	116.04 ± 4.7 116.36 (102.75 - 132.37)	25.49 ± 3.64 25.57 (15.78 - 36.74)	44.14 ± 6.87 44.05 (26.54 - 59.15)	61.43 ± 2.77 61.02 (52.3 - 76.65)
Left	425(50)	30.59 ± 3.48 30.41 (21.2 - 39.98)	116.08 ± 4.59 116.52 (102.69 - 132.88)	25.52 ± 3.60 25.52 (16.2 - 36.71)	44.14 ± 6.88 44.12 (28.02 - 66.34)	61.45 ± 2.7 61.02 (52.6 - 74.52)
p*		0.945	0.974	0.887	0.928	0.940
Sex						
Male	216(50.8)	30.54 ± 3.63 30.56 (21.13 - 39.98)	115.58 ± 4.79 116.22 (102.69 - 128.82)	25.2 ± 3.64 25.21 (15.78 - 34.45)	44.14 ± 7.01 44.64 (27.6 - 66.34)	61.22 ± 2.68 60.65 (52.46 - 69.32)
Female	209(49.2)	30.65 ± 3.38 30.32 (22.11 - 38.51)	116.55 ± 4.44 116.64 (102.84 - 132.88)	25.82 ± 3.57 25.67 (16.82 - 36.74)	44.13 ± 6.75 43.91 (26.54 - 59.15)	61.66 ± 2.77 61.59 (52.3 - 76.65)
p*		0.846	**0.011**	0.053	0.858	**<0.001**
Age Groups						
18-29	87(20.5)	31.64 ± 3.52 30.94 (22.11 - 38.99)[b]	115.68 ± 4.33 115.93 (106.05 - 128.82)	25.76 ± 4.11 25.85 (15.78 - 36.61)[ab]	44.23 ± 7 44.79 (26.54 - 56.3)[b]	61.07 ± 2.88 60.84 (52.46 - 68.91)[a]
30-39	81(19.1)	30.85 ± 3.86 30.2 (21.37 - 39.98)[ab]	115.69 ± 4.85 116.22 (102.69 - 132.88)	25.42 ± 3.49 25.6 (17.27 - 34.81)[bc]	44.38 ± 6.50 43.93 (28.78 - 66.34)[b]	61.67 ± 2.32 61.45 (56.48 - 68.65)[ab]
40-49	83(19.5)	29.91 ± 3.9 30.08 (21.13 - 38.51)[a]	116.76 ± 5.17 116.68 (103.23 - 130.20)	24.48 ± 3.43 24.19 (18.12 - 35.41)[c]	43.16 ± 6.48 43.22 (30.55 - 57.08)[b]	61.32 ± 2.79 60.92 (53.56 - 76.65)[ab]
50-59	83(19.5)	30.01 ± 3.29 30.25 (21.44 - 38.27)[a]	116.46 ± 4.27 116.39 (102.84 - 126.52)	25.95 ± 3.74 25.78 (17.56 - 36.74)[ab]	43.46 ± 7.49 42.72 (30.68 - 56.56)[b]	61.29 ± 2.6 60.78 (55.26 - 69.75)[a]
60-69	62(14.6)	30.54 ± 2.99 30.62 (22.3 - 36.2)[ab]	115.97 ± 4.4 116.77 (104.62 - 125.78)	25.07 ± 2.78 25.35 (18.19 - 33.33)[bc]	43.73 ± 6.97 44.41 (27.6 - 57.56)[b]	62.21 ± 2.53 61.74 (56.98 - 69.51)[b]
70+	29(6.8)	30.46 ± 1.71 30.34 (27.65 - 35.62)[ab]	115.26 ± 4.73 116.34 (104.45 - 124.21)	27.49 ± 3.14 26.55 (22.89 - 33.72)[a]	48.78 ± 4.55 48.53 (40.26 - 59.15)[a]	61 ± 3.56 60.28 (52.3 - 70.23)[a]
p**		**0.002**	0.184	**<0.001**	**<0.001**	**<0.001**

*Mann-Whitney U test; **Kruskal-Wallis test; a-c: Groups sharing the same letter do not differ significantly.

When evaluating the relationship between calcaneal angles and body height by side, the FPA showed a significant negative correlation with height on the right, left, and both feet (right: r = -0.146, p = 0.003; left: r = –0.163, p = 0.001; bilateral: r = –0.155, p<0.001). This finding indicates that FPA values decrease as height increases. When the relationship between the angles and height was analyzed by sex, a positive correlation was found between the BA and height in males (r = 0.185, p<0.001). In females, a positive correlation was identified between the GA and height (r = 0.148, p = 0.003), while a negative correlation was found between the CIA and height (r = -0.141, p = 0.004). These findings suggest that with increasing height, BA tends to increase in males, while GA increases and CIA decreases in females.

When the relationship between calcaneal angles and body weight was evaluated by side, CIA was found to have a significant negative correlation with body weight in the right, left, and both feet (right: r = -0.127, p = 0.009; left: r = -0.127, p = 0.009; bilateral: r = -0.128, p = 0.008). The LTCA also had a weak negative correlation with body weight in all three comparisons (right: r = -0.149, p<0.001; left: r = -0.146, p = 0.003; bilateral: r = -0.146, p = 0.003). FPA exhibited a weak negative correlation with body weight only on the left side and bilaterally (left: r = -0.108, p = 0.026; bilateral: r = -0.097, p = 0.005). Considering sex, BA showed a positive correlation with body weight in males (r = 0.139, p = 0.004), while both CIA and LTCA were negatively correlated (r = -0.156, p = 0.001 and r = -0.137, p = 0.004, respectively). In females, only LTCA has a significant negative correlation with body weight (r = -0.193, p<0.001). A summary of the relationships between calcaneal angles, height, and body weight according to side and sex is presented in Table II.

Table II. Analysis of the relationship between calcaneal angles and body height and weight by side and sex.

		BA (r;p)	GA (r;p)	CIA (r;p)	LTCA (r;p)	FPA (r;p)
Body Height						
Side						
	Both feet	0.056;0.102	-0.019;0.576	-0.062;0.073	0.011;0.755	-0.155;**<0.001**
	Right foot	0.064;0.188	-0.017;0.725	-0.053;0.272	0.008;0.870	-0.146;**0.003**
	Left foot	0.049;0.317	-0.022;0.654	-0.069;0.158	0.014;0.781	-0.163;**0.001**
Sex						
	Male	0.185;**<0.001**	-0.011;0.814	0.066;0.174	0.087;0.071	-0.057;0.240
	Female	0.008;0.864	0.148;**0.003**	-0.141;**0.004**	-0.085;0.081	-0.075;0.125
Body Weight						
Side						
	Both feet	0.066;0.055	0.025;0.462	-0.128;**<0.001**	-0.149;**<0.001**	-0.097;**0.005**
	Right foot	0.071;0.143	0.028;0.562	-0.127;**0.009**	-0.146;**0.003**	-0.087;0.074
	Left foot	0.06;0.214	0.022;0.653	-0.128;**0.008**	-0.152;**0.002**	-0.108;**0.026**
Sex						
	Male	0.139;**0.004**	0.088;0.068	-0.156;**0.001**	-0.137;**0.004**	-0.057;0.242
	Female	0.003;0.949	0.044;0.368	-0.091;0.062	-0.193;**<0.001**	-0.044;0.365

Factors influencing BA, GA, CIA, LTCA, and FPA were assessed using linear regression analysis, and the models were determined to be significant (BA: F = 3.961, p = 0.003; GA: F = 5.212, p<0.001; CIA: F = 7.395, p<0.001; LTCA: F = 6.719, p<0.001; FPA: F = 2.870, p = 0.022) (Table III).

Age was associated with a 0.025° decrease in BA for each additional year (p = 0.001). GA was, on average, 1.854° higher in females than in males (p<0.001), and each 1 cm increase in height was associated with a 0.075° increase in GA (p = 0.001). Each 1 kg increase in body weight was associated with decreases of 0.051° in CIA (p<0.001), 0.104° in LTCA (p<0.001), and 0.019° in FPA (p = 0.024). No other variables demonstrated a statistically significant effect on the calcaneal angles (p>0.05).

DISCUSSION

Calcaneal angles are among the commonly utilized parameters in the diagnosis of foot deformities such as calcaneal fractures, pes planus, pes cavus, pes equinovarus, pes planovalgus, Haglund deformity, and metatarsus varus (Schepers *et al*., 2007; Seyahi *et al*., 2009; Tourné *et al*., 2018). Moreover, both in the preoperative and postoperative periods, the comparative use of calcaneal angles in surgical decision-making, bone alignment, anatomical restoration planning, morbidity assessment, and prognosis prediction plays a critical role in clinical decision-making processes (Schepers *et al*., 2007; Van Hoeve *et al*., 2015).

Many studies clearly demonstrated the decisive role of calcaneal angles in surgical success and functional outcomes. Van Hoeve *et al*. (2015) reported that insufficient restoration of BA negatively affects postoperative outcomes. Nooijen *et al*. (2021), stated that proper correction of this angle significantly reduces foot and ankle pain. Sugimoto *et al*. (2022), found that preserving the postoperative BA reduces pain and improves AOFAS scores, and that loss of angle correlates with increased postoperative pain. Similarly, Polat *et al*. (2011), reported that maintaining GA within anatomical limits after surgery improves the Maryland Foot Score and enhances in both functional capacity and pain levels. These findings suggest that anatomical reduction of calcaneal angles is very important not only for radiological outcomes but also for functional results.

Previous studies reported that reference values for calcaneal angles differ significantly across populations, highlighting the need to establish population-specific normative ranges for accurate clinical application (Seyahi *et al*., 2009; Shoukry *et al*., 2012; Igbigbi & Mutesasira, 2013). In this context, the present study supports earlier findings on ethnic and geographic variability by demonstrating that the mean values and distribution ranges of calcaneal angles in the Turkish population differ from those reported in most other populations in the literature, with the exception of the series of Tourné *et al*. (2018) (Table IV).

Conflicting results were reported in the literature regarding the relationship between calcaneal angles and sex. While most studies report no significant differences (Thomas *et al*., 2003; Seyahi *et al*., 2009; Shoukry *et al*., 2012; Dahiru *et al*., 2013; Gutierrez *et al*., 2013; Katchy *et al*., 2018; Da Silva Louro *et al*., 2020), some noted sex-specific variations in certain angles (Igbigbi & Mutesasira, 2013;

Table III. Results of linear regression analysis of factors affecting calcaneal angles (BA, GA, CIA, LTCA, and FPA).

		β_0 (%95 CI)	S. Hata	β_1	t	p	r^1	r^2	VIF
BA	Intercept	26.769 (20.364 - 33.174)	3.263		8.203	**<0.001**			
	Sex (Male)	Reference							
	Female	0.57 (-0.048 - 1.187)	0.315	0.081	1.811	0.071	0.016	0.062	1.735
	Age	-0.025 (-0.041 - -0.01)	0.008	-0.114	-3.208	**0.001**	-0.115	-0.11	1.086
	Height (cm)	0.021 (-0.013 - 0.056)	0.017	0.055	1.221	0.222	0.04	0.042	1.727
	Weight (kg)	0.016 (-0.005 - 0.037)	0.011	0.053	1.496	0.135	0.035	0.051	1.076
	F=3.961, p=0.003, R2=%1.8, Adjusted R2=%1.4, β0: Unstandardized beta coefficient, β 1:Standardized beta coefficient, r1: Zero-order correlation, r2: Partial correlation								
GA	Intercept	101.131 (92.668 - 109.594)	4.312		23.455	**<0.001**			
	Sex (Male)	Reference							
	Female	1.854 (1.038 - 2.67)	0.416	0.2	4.461	**<0.001**	0.105	0.152	1.735
	Age	0.009 (-0.012 - 0.029)	0.01	0.03	0.843	0.400	0.023	0.029	1.086
	Height (cm)	0.075 (0.03 - 0.121)	0.023	0.146	3.266	**0.001**	0.017	0.112	1.727
	Weight (kg)	0.015 (-0.013 - 0.042)	0.014	0.037	1.061	0.289	0	0.036	1.076
	F=5.212, p<0.001, R2=%2.4, Adjusted R2=%1.9, β 0: Unstandardized beta coefficient, β 1: Standardized beta coefficient, r1: Zero-order correlation, r2: Partial correlation								
CIA	Intercept	31.896 (25.334 - 38.457)	3.343		9.541	**<0.001**			
	Sex (Male)	Referans							
	Female	0.104 (-0.528 - 0.737)	0.322	0.014	0.323	0.747	0.086	0.011	1.735
	Age	0.005 (-0.011 - 0.021)	0.008	0.021	0.605	0.545	0.033	0.021	1.086
	Height (cm)	-0.018 (-0.053 - 0.017)	0.018	-0.045	-1.01	0.313	-0.072	-0.035	1.727
	Weight (kg)	-0.051 (-0.073 - -0.03)	0.011	-0.166	-4.734	**<0.001**	-0.172	-0.161	1.076
	F=7.395, p<0.001, R2=%3.4, Adjusted R2=%2.9, β 0: Unstandardized beta coefficient, β 1: Standardized beta coefficient, r1: Zero-order correlation, r2: Partial correlation								
LTCA	Intercept	49.381 (36.9 - 61.863)	6.359		7.765	**<0.001**			
	Sex (Male)	Referans							
	Female	-0.611 (-1.814 - 0.592)	0.613	-0.044	-0.997	0.319	-0.001	-0.034	1.735
	Age	0.021 (-0.009 - 0.051)	0.015	0.048	1.368	0.172	0.035	0.047	1.086
	Height (cm)	0.009 (-0.058 - 0.076)	0.034	0.012	0.263	0.793	0.013	0.009	1.727
	Weight (kg)	-0.104 (-0.145 - -0.063)	0.021	-0.177	-5.028	**<0.001**	-0.164	-0.17	1.076
	F=6.719, p<0.001, R2=%3.1, Adjusted R2=%2.6 β 0: Unstandardized beta coefficient, β 1: Standardized beta coefficient, r1: Zero-order correlation, r2: Partial correlation								
FPA	Intercept	61.544 (56.54 - 66.549)	2.55		24.138	**<0.001**			
	Sex (Male)	Reference							
	Female	0.353 (-0.13 - 0.836)	0.246	0.065	1.436	0.151	0.08	0.049	1.735
	Age	0.006 (-0.006 - 0.018)	0.006	0.034	0.947	0.344	0.039	0.033	1.086
	Height (cm)	0.005 (-0.022 - 0.031)	0.014	0.015	0.345	0.730	-0.04	0.012	1.727
	Weight (kg)	-0.019 (-0.035 - -0.002)	0.008	-0.08	-2.259	**0.024**	-0.094	-0.078	1.076
	F=2.87, p=0.022, R2=%1.3, Adjusted R2=%0.9 β 0: Unstandardized beta coefficient, β 1: Standardized beta coefficient, r1: Zero-order correlation, r2: Partial correlation								

r: Spearman's rho correlation coefficient

Ramachandran & Shetty, 2015; Alkenani *et al*., 2017; Katchy *et al*., 2018; Zivanovic-Macuzic *et al*., 2018). For example, Igbigbi & Mutesasira (2013), reported significantly higher BA values in females compared to males, Katchy *et al*. (2018) observed similar findings for the LTCA, and Alkenani *et al*. (2017) for the CIA. Igbigbi & Mutesasira (2013) also emphasized the importance of adequate sample sizes when evaluating such differences. In the present study, which included a large sample of 850 subjects, significant sex-based differences were observed in GA and FPA values. The GA was 1.854° higher in females than in males (p<0.001), and a similar significant difference was found for FPA (p<0.001). These findings support the consideration of sex as a relevant factor in the evaluation of GA and FPA.

Table IV. Comparison of the values reported in the literature for calcaneal angles with the findings of this study.

Angle	Study (Year)	Population	n	Age	Min.-Max.	Mean±S.D. (°)	p*
BA	Igbigbi & Mutesasira (2003)	Ugandans	114	20-40	20-50	35.1±27.5	**<0.001**
BA	Khoshhal *et al*. (2004)	Saudi Arabians	229	15-72	16-47	31.2±5.6	0.649
BA	Thomas *et al*. (2006)	British	200	19-76	21.1-47.3	32.2±5.0	**<0.001**
BA	Shoukry *et al*. (2012)	Egyptian	220	20-40	22-40	30.14±4.18	**0.026**
BA	Kang *et al*. (2012)	American	50	18+	-	33.3	**<0.001**
BA	Zivanovic-Macuzic *et al*. (2018)	Serbian	225	15-75	25.1-49.5	34.1±4.2	**<0.001**
BA	da Silva Louro *et al*. (2020)	Brazilian	800	18-92	-	32.6±6.1	**<0.001**
BA	Present study (2025)	Turkish	850	18-87	21.13-39.98	30.59 ± 3.5	
GA	Khoshhal *et al*. (2004)	Saudi Arabians	229	15-72	96-152	116.2±8.5	**<0.001**
GA	Shoukry *et al*. (2012)	Egyptian	220	20-40	108-138	122.9±6.95	**<0.001**
GA	Ramachandran & Shetty (2015)	Indian	184	17-75	87.5-137.8	108.5±11.43	**<0.001**
GA	Katchy *et al*. (2020)	Nigerians	120	18-64	-	121.22±6.11	**<0.001**
GA	Da Silva Louro *et al*. (2020)	Brazilian	800	18-92	-	110.6±11.9	**<0.001**
GA	Present study (2025)	Turkish	850	18-87	102.69 -	116.06±4.64	
CIA	Thomas *et al*. (2006)	British	200	19-76	5.2-43.3	19.6±6.2	**<0.001**
CIA	Schepers *et al*. (2007)	Dutch	33	18-65	12-33	23	**<0.001**
CIA	Present study (2025)	Turkish	850	18-87	15.78-36.74	25.5±3.62	
LTCA	Thomas *et al*. (2006)	British	200	19-76	25.5-68.2	45.9±7.5	**<0.001**
LTCA	Schepers *et al*. (2012)	Dutch	33	18-65	32-58	43	**<0.001**
LTCA	Dahiru *et al*. (2013)	Nigerians	302	-	18-56	38.85±8.2	**<0.001**
LTCA	Present study (2025)	Turkish	850	18-87	26.54-66.34	44.14±6.87	
FPA	Kang *et al*. (2012)	American	50	18+	-	61.0	**0.008**
FPA	Tourné *et al*. (2018)	French	30	19-67	36-69.5	59±0.3	0.816
FPA	Present study (2025)	Turkish	850	18-87	52.3-76.65	61.44±2.73	

*Runs test.

The relationship between calcaneal angles and age was investigated in various studies, and many researchers emphasized the importance of evaluating differences across age groups (i.e., decades) (Thomas *et al*., 2003; Da Silva Louro *et al*., 2020). In the present study, which included a homogenous distribution of cases and a large number of series, it was observed that BA, CIA, LTCA, and FPA measurements varied significantly across age decades, whereas GA did not. Some studies reported no association between BA and age (Khoshhal *et al*., 2004; Ramachandran & Shetty, 2015; Katchy *et al*., 2018; Da Silva Louro *et al*., 2020), while others, in line with the findings achieved in this study, reported that BA decreases with age (Shoukry *et al*., 2012; Zivanovic-Macuzic *et al*., 2018). Regarding GA, consistent with many previous studies, no significant relationship with age was found in this study (Khoshhal *et al*., 2004; Shoukry *et al*., 2012; Ramachandran & Shetty, 2015; Da Silva Louro *et al*., 2020; Katchy *et al*., 2018). Alkenani *et al*. (2017), Katchy *et al*. (2018) and Thomas *et al*. (2003) also reported no significant correlation between CIA and age. However, in the present study, CIA varied significantly across age groups, with the highest mean value of 27.49 ± 3.14° observed in individuals aged 70 and older. Katchy *et al*. (2018) reported an inverse correlation between LTCA and age, while the findings achieved in this study supported those of Thomas *et al*. (2003) who noted that LTCA increases with age, with the highest mean value found in the 70+ age group. Gutierrez *et al*. (2013) reported a negative correlation between FPA and age. In the present study, FPA also showed significant variation across decades, with the highest mean observed in the 7th decade. Seyahi *et al*. (2009) found no significant relationship between BA and GA and age, and suggested that, if available, older radiographs could be used for evaluation in cases with calcaneal fractures. The linear regression analyses revealed that for each one-year increase in age, the BA decreased by an average of 0.025°. Therefore, it is recommended that in patients with previous radiographs, a correction of 0.025° per year of age difference should be applied when evaluating BA, rather than relying solely on past measurements as reference values.

Previous studies reported no significant differences in calcaneal angles between sides (right/left) (Thomas *et al*., 2003; Khoshhal *et al*., 2004; Seyahi *et al*., 2009; Shoukry *et al*., 2012; Dahiru *et al*., 2013; Alkenani *et al*., 2017; Alabi *et al*., 2020). Consistent with these findings, this study also yielded no significant difference between sides in terms of the BA, GA, CIA, LTCA, and FPA. These results indicate that side asymmetry in calcaneal angles is not clinically significant and support the use of the contralateral intact side as a reference in the presence of unilateral lesions.

Shoukry *et al*. (2012) reported no significant relationship between body mass index (BMI) and either BA or GA. Apart from this finding, there still is a gap in the literature regarding the association of calcaneal angles with body weight and height. The present study is the first comprehensive study examining the relationship between calcaneal angles and body height and weight in detail, taking both side and sex variables into account. Given the findings achieved in this study, when analyzing the association between height and calcaneal angles by side, a significant negative correlation was observed for FPA. When examining the relationship of height with calcaneal angles by sex, it was found that as height increased, BA increased in males and GA increased in females, whereas CIA decreased in females. Regarding body weight, side-specific analyses revealed significant negative correlations between CIA, LTCA, and FPA. When evaluated by sex, weight gain in males was associated with an increase in BA and decreases in CIA and LTCA, whereas an increase in weight was associated with a decrease in LTCA in females. Regression analysis addressing the effects of sex, age, height, and body weight on calcaneal angles demonstrated that each 1 cm increase in height led to a 0.075° increase in GA, whereas each 1 kg increase in body weight resulted in decreases of 0.051° in CIA, 0.104° in LTCA, and 0.019° in FPA. These findings highlight the sensitivity of calcaneal angles to variations in body height and weight, emphasizing the importance of considering these parameters during clinical evaluation.

CONCLUSIONS

In the assessment of calcaneal angles, it is essential to consider not only population-based reference values but also individual variables such as age, sex, height, and body weight. Given the absence of significant differences between sides, radiographs of the unaffected contralateral foot can be reliably used as a reference. GA and FPA values were significantly associated with sex, with GA being on average 1.854° higher in females than in males. BA, CIA, LTCA, and FPA were found to vary with age, with BA showing a decrease of approximately 0.025° per year. Furthermore, for each 1 cm increase in height, GA increased by 0.075°, whereas each 1 kg increase in body weight was associated with decreases of 0.051°, 0.104°, and 0.019° in CIA, LTCA, and FPA, respectively. These data suggest that establishing individualized normative reference values may enhance diagnostic accuracy, positively influence clinical outcomes, and contribute to improved postoperative pain management.

ALTUNTAS, E.; UZUN, A. & BAS, O. Relación de los ángulos calcáneos con la edad, el sexo, la lateralidad, la altura y el peso corporal. *Int. J. Morphol., 44(1)*:23-31, 2026.

RESUMEN: Este estudio tuvo como objetivo investigar la relación entre los ángulos de Böhler (BA), Gissane (GA), inclinación calcánea (CIA), talus-calcáneo lateral (LTCA) y Fowler-Philip (FPA), que desempeñan un papel importante en el diagnóstico de deformidades del pie y en la toma de decisiones clínicas y quirúrgicas, como también en la edad, el sexo, la lateralidad, la altura y el peso corporal. Además, este estudio busca establecer valores de referencia normativos específicos para cada individuo. Se analizaron radiografías laterales del pie con carga bilateral (n=850) de 425 individuos (216 hombres, 209 mujeres; edad media: 45,14 ± 15,82 años) sin patología podal. Los valores medios fueron: BA: 30,59 ± 3,5°, GA: 116,06 ± 4,64°, CIA: 25,5 ± 3,62°, LTCA: 44,14 ± 6,87° y FPA: 61,44 ± 2,73°. Se observaron diferencias significativas en comparación con las mediciones reportadas en otras poblaciones. BA, CIA, LTCA y FPA mostraron diferencias significativas entre los grupos de edad (BA: p=0,002; CIA: p<0,001; LTCA: p<0,001; FPA: p<0,001). GA y FPA exhibieron diferencias significativas relacionadas con el sexo (GA: p = 0,011; FPA: p < 0,001). No se determinó una correlación significativa entre los ángulos y el lado. En los hombres, BA se correlacionó positivamente con la altura (r = 0,185, p < 0,001), mientras que GA mostró una correlación positiva (r = 0,148, p = 0,003) y CIA una correlación negativa (r = -0,141, p = 0,004) con la altura en las mujeres. Con respecto al peso corporal, BA se correlacionó positivamente en los hombres (r = 0,139, p = 0,004), mientras que CIA (r = -0,156, p = 0,001) y LTCA (r = -0,137, p = 0,004) mostraron correlaciones negativas. En las mujeres, LTCA también se correlacionó negativamente con el peso (r = -0,193, p < 0,001). Según el análisis de regresión, la edad se asoció con una disminución de 0,025° en la BA por año (p = 0,001). La GA fue, en promedio, 1,854° mayor en mujeres que en hombres (p < 0,001). Cada aumento de 1 cm en la altura se relacionó con un aumento de 0,075° en la GA (p = 0,001), mientras que cada aumento de 1 kg en el peso corporal se relacionó con disminuciones de 0,051° en la CIA (p < 0,001), 0,104° en la LTCA (p < 0,001) y 0,019° en la FPA (p = 0,024). Estos hallazgos resaltan la necesidad de considerar la edad, el sexo, la altura y el peso corporal, además de los valores de referencia poblacionales, al evaluar los ángulos calcáneos.

PALABRAS CLAVE: Calcáneo; Ángulos; Factores de edad; Altura; Peso corporal.

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