.

Citation: *Egypt.Acad.J.Biolog.Sci. (C.Physiology and Molecular biology) Vol. 17(2) pp203-211 (2025)*
DOI: 10.21608/EAJBSC.2025.457600

Egypt. Acad. J. Biolog. Sci., 17(2):203-211 (2025)
Egyptian Academic Journal of Biological Sciences
C. Physiology & Molecular Biology
ISSN 2090-0767
www.eajbsc.journals.ekb.eg

Estimation of Gender Via Calcaneus Radiological Examinations among Egyptian Populations

Nehal E. Refaay [1&3]*, Reham F. Mansour [2] and Nehal A. Bahaa El-Din [3]
[1]Department of Physical Therapy, College of Applied Medical Sciences, Qassim University, Buraidah, Saudi Arabia.
[2]Radiodiagnosis department, Faculty of Medicine, Zagazig University, Egypt.
[3] Human Anatomy & Embryology Department, Faculty of Medicine, Zagazig University, Egypt
E-mail: nehal.roaa@yahoo.com ; n.refaei@qu.edu.sa

ARTICLE INFO
Article History
Received: 30/8/2025
Accepted: 6/10/2025
Available:10/10/2025

Keywords:
Calcaneus, sex identification, radiographs, metric values.

ABSTRACT

Introduction: Bone measurements reveal data concerning both each person and the population to which they belong. The skull and pelvis skeleton are usually used in sex determination; however, the calcaneus is ideal for identifying sex because of its robust composition and resilience against alterations occurring after death. Comparative analysis of calcaneal radiographs allows sex identification for unknown corpses. Methods: This study utilized patient radiographs from the Radiology Department of Zagazig University Hospitals. The study included 54 people (27 males and 27 females) with normal calcanei. The metric values have been taken for seven calcaneus parameters, including maximum width, body width, maximum length, minimum length, the height of the facies articularis cuboidea, tuber angle, and the anterior angle. Results: This study found some significant differences in calcaneal measures among male and female individuals. Males had considerably higher calcaneal dimensions in all studied parameters, including maximum width, body width, maximum and minimum lengths, facies cuboidea height, and angular measurements (tuber and anterior angles). There was a substantial difference in calcaneal anatomy across genders ($P < 0.05$). Conclusion: The present study highlights the calcaneal significance in determining gender as well as it offers calcaneus as an effective substitute tool in forensic anthropological sciences in addition to many other sciences.

INTRODUCTION

The feet's structural characteristics allow them to transport and convey the body's weight to the earth through life without the need for any additional organs. The calcaneal bone is the biggest, longest, and strongest of the foot's 7 tarsal bones. The calcaneus is a bone resembles the shape of box which constitutes the heel in foot's rear and constitutes one of the sections that comes in contact with the ground. Its joint surfaces and shapes are intricate (Anatomy, 2008, Amuti *et al.,* 2020)

The calcaneus is a key component in the force transmission between the body and the ground because of its location and shape. It is essential for supporting weight because of its intricacy and the numerous joints it shares in them which subsequently unite the ankle to the hindfoot (Schmutz *et al.,* 2021). In addition, it serves as the Achilles tendon's short lever arm (Mahan *et al.,* 2020). The calcaneal tubercle is the bony portion near the heel. Both Calcaneal processes (medial and lateral ones) mark abductor hallucis and abductor digiti minimi muscles origins, are located on each side of its distal edge (Rohen *et al.,* 2002).

An essential task for forensic and physical anthropologists is determining the sex of a mature adult skeleton. Identifying the gender of an individual's skeleton, regardless of its preservation condition, is crucial in these professions. Several approaches are used to determine a skeleton's sex: DNA analysis, morphological trait observation, and the application of metrical data with discriminatory function. When it comes to determining sex, molecular approaches are the most powerful. The morphological techniques are straightforward and incredibly accurate. These approaches, yet, are frequently arbitrary and rely on the observer's background. Applying discriminant analysis can improve the accuracy of gender identification and lessen subjectivity, particularly in situations with inadequate maintenance (Scheuer, 2002). Research on determining sex have examined several skeletal components. According to Washburn's research on gender identification across numerous cultures, pelvic region produced the best outcomes (Washburn, 1948). In contrast, gender can be ascertained with 80% certainty utilizing the skull, with 90% assurance utilizing the head and mandibles, and 80% certainty utilizing the pelvis according to (Buran et al., 2018). According to earlier researches, calcaneus assessments were very useful for assessing gender in a variety of populations as well in older human remains. The calcaneus typically has good durability because of its form and the dense nature of bone trabeculae (Sakaue, 2011). It also can tolerate significant tension stress because it is frequently worn in shoes during everyday activities, it is a bone that has more protection from environmental influences (Bidmos and Asala, 2004, Scott *et al.,* 2017).

Therefore, this research aims to record some calcaneus lengths measurements using feet radiographs in the Egyptian population and assess how well the results predict gender.

MATERIALS AND METHODS

Radiographs used in this cross sectional study were obtained from Zagazig University Hospitals. Anatomically normal calcanei from 45 individuals 27 males and 27 females were used (Ethics committee approval numbered (822/5-Nov-2024). Calculations were estimated using openEpi at power 80%and confidence level 95%.

Patients who are part of the study were asked for their informed consent. We performed the metric evaluations using the eFlim tool, that is suitable for the PACS system utilized at Zagazig university Hospital, following identifying each of the subsequent measurements determined by calcaneus' latero-lateral radiographical images (Uzuner *et al.,* 2016) of male(Figs. 1 & 2) and female (Figs. 3 &4).

-Maximum width (a-f): the space from the top location at facies articularis cuboidea's height to the most posterior location on the calcaneus bone.

-Body width(a–g): the space that begins at the fascia articularis cuboidea's height's lowest portion ending with the most calcaneal posterior portion.

-Maximum length(b-c): the space from the calcaneus's most superior to most inferior regions.

-Minimum length(d-e): the space from the deepest regions of calcaneus's uppermost surface and its lowermost one .

-The height of facies articularis cuboidea(f-g): The space from facies articularis cuboidea's summits to its most inferior parts.

-Tuber angle (α): The angled shape created by the lines from the summit of the facies articularis cuboidea to the most frontal location of the calcaneus' upper aspect and the line joining the most anterior region of this surface towards the farthest dorsal location on this surface's plane.

-The anterior angle (β): is the angled shape formed by the line connecting the lowest region of the facies articularis cuboidea to the inferior surface of the calcaneus's most dorsal point and the line connecting the lowest location of the cuboidea to the superior surface's most posterior location.

Fig. 1:(33-year-old male): Metric values showing maximum width (a–f), body width (a–g), maximum length (b-c), minimum length (d-e), along with height of facies articularis cuboidea (f-g).

Fig. 2: (33-year-old male): Tuber angle (α)along with anterior angle (β) .

Fig. 3:(46-year-old female): metric values showing maximum width (a–f), body width (a–g), maximum length (b-c), minimum length (d-e), as well as height of facies articularis cuboidea (f-g).

Fig.4: (46-year-old female): Tuber angle (α)along with anterior angle (β).

3- Statistical Analysis:

All information was gathered, tallied, then evaluated in statistical terms via IBM Corp., which was published in 2015. Statistics for Windows, IBM SPSS, Version 23.0. IBM Corp. Armonk, NY. For quantitative data after testing normality using the Shapiro-Wilk test: normally distributed data presented with mean ± SD. Qualitative data were expressed as numbers and percentages. The chi-square and Fisher's exact tests were used for qualitative data, while the student t-test was used for quantitative data. Employing components found with a p-value < 0.05 in univariate analysis, a multivariable logistic regression model was used to evaluate the determinants of male's gender using a forward technique. ROC was used to determine the cut-off value of the calcaneal parameters, and cross tabs were made to determine their specificity as well as sensitivity. Every test had two sides. Statistical significance was defined as a p-value ≤ 0.05, while statistical insignificance was defined as a p-value > 0.05.

RESULTS

The Cross-sectional study revealed several significant findings regarding the calcaneal measurements between male and female patients. Notably, males exhibited significantly larger calcaneal dimensions across all measured parameters, including maximum width, body width, maximum and minimum lengths, height of the facies cuboidea, and angular measurements (tuber and anterior angles). These differences were statistically significant (P < 0.05), indicating a clear dimorphism in calcaneal structure based on gender (Table 1).

Correlation analyses further highlighted notable associations among various calcaneal parameters. Maximum width showed strong positive correlations with other dimensions such as body width and maximum length (P < 0.001 and P = 0.005, respectively), suggesting a consistent proportionality in bone architecture. Similarly, the anterior angle demonstrated significant correlations with multiple other variables, which may reflect biomechanical interdependence within the calcaneal morphology (Table 2).

Logistic regression analysis identified several calcaneal measurements as independent predictors of male gender. In multivariate analysis, maximum width, maximum length, height of the cuboidea, and anterior angle remained significant predictors, suggesting that these parameters could potentially serve as reliable indicators in sex differentiation (Table 3).

ROC curve analysis provided additional evidence supporting the discriminative value of calcaneal measurements. Maximum width and body width demonstrated high specificity (85.19% and 96.3%, respectively), while maximum length showed the highest sensitivity (88.89%). These metrics, particularly the AUC values, affirm the diagnostic potential of calcaneal dimensions in predictive modeling (Table 4 and Fig. 5).

Table 1: Age and calcaneal measurements among the studied groups

Variables		Male (n=27)	Female (n=27)	P Value
Age *(years)*	*Mean ± SD*	41.7 ± 12.2	40.3 ± 12.5	0.68
	Range	(20 – 60)	(20 – 60)	
Maximum width *(mm)*	*Mean ± SD*	52.4 ± 3.75	47.8 ± 3.89	**<0.001**
	Range	(45.2 – 59.4)	(41 – 54.6)	
Body width *(mm)*	*Mean ± SD*	38.5 ± 3.45	35.7 ± 2.33	**0.001**
	Range	(32.7 – 44.7)	(29.6 – 38.8)	
Maximum length *(mm)*	*Mean ± SD*	79.1 ± 5.9	73.9 ± 6.49	**0.003**
	Range	(68.9 – 88.9)	(63 – 81.6)	
Minimum length *(mm)*	*Mean ± SD*	61.5 ± 4.02	58.7 ± 3.59	**0.01**
	Range	(54.5 – 69.7)	(50.7 – 63.9)	
Height of facies cuboidea *(mm)*	*Mean ± SD*	21.4 ± 2.66	19.3 ± 2	**0.001**
	Range	(17.2 – 25.6)	(15.3 – 22.5)	
Tuber angle *(α)*	*Mean ± SD*	45.6 ± 4.14	42.5 ± 3.78	**0.006**
	Range	(39.2 – 52)	(36.6 – 47.6)	
Anterior angle *(β)*	*Mean ± SD*	36.5 ± 3.57	33.8 ± 3.94	**0.009**
	Range	(30.3 – 42.7)	(28.4 – 39.2)	

**Independent sample t-test, Non-significant: P >0.05, Significant: P ≤0.05*

Table 2: Correlation between calcaneal parameters and gender among the studied patients

		Gender	**Max. width**	**Body width**	**Max. length**	**Min. length**	**Height of facies**	**Tuber angle**	**Anterior angle**
Age	*r*	0.058	0.062	0.189	0.218	0.056	0.001	0.229	0.072
	P	0.68	0.67	0.17	0.11	0.69	0.99	0.09	0.61
Maximum width *(mm)*	*r*	0.524	-	0.375	0.083	0.323	0.198	0.159	0.309
	P	**<0.001**	**-**	**0.005**	0.55	**0.02**	0.15	0.25	**0.02**
Body width *(mm)*	*r*	0.431	0.375	-	0.023	0.092	0.097	0.132	0.425
	P	**0.001**	**0.005**	-	0.87	0.51	0.49	0.34	**0.001**
Maximum length *(mm)*	*r*	0.396	0.083	0.023	-	0.294	0.173	0.428	0.383
	P	**0.003**	0.55	0.87	**-**	**0.03**	0.21	**0.001**	**0.004**
Minimum length *(mm)*	*r*	0.343	0.323	0.092	0.294	-	0.032	0.172	0.153
	P	**0.01**	**0.02**	0.51	**0.03**	-	0.82	0.21	0.27
Height of facies cuboidea	*r*	0.442	0.198	0.097	0.173	0.032	-	0.098	0.015
	P	**0.001**	0.15	0.49	0.21	0.82	-	0.48	0.91
Tuber angle *(α)*	*r*	0.373	0.159	0.132	0.428	0.172	0.098	-	0.205
	P	**0.006**	0.25	0.34	**0.001**	0.21	0.48	-	0.14
Anterior angle *(β)*	*r*	0.353	0.309	0.425	0.383	0.153	0.015	0.205	-
	P	**0.009**	**0.02**	**0.001**	**0.004**	0.27	0.91	0.14	-

**Pearson's correlation test, Non-significant: P >0.05, Significant: P ≤0.0*

Table 3: Logistic regression analysis for predictors of male gender.

Variables	**Univariate analysis**		**Multivariate analysis**	
	P value	**Odds (CI 95%)**	**P value**	**Odds (CI 95%)**
Age	0.67	0.99 (0.95 – 1.04)	-	-
Max. width	**0.001**	1.39 (1.14 – 1.71)	**0.03**	1.4 (1.03 – 1.89)
Body width	**0.004**	1.39 (1.11 – 1.74)	0.07	1.56 (0.97 – 2.5)
Max. length	**0.007**	1.15 (1.04 – 1.27)	**0.04**	1.23 (1.01 – 1.5)
Min. length	**0.02**	1.22 (1.03 – 1.44)	0.28	1.18 (0.87 – 1.6)
Height of cuboidea	**0.004**	1.47 (1.13 – 1.92)	**0.03**	1.69 (1.07 – 2.67)
Tuber angle	**0.009**	1.22 (1.05 – 1.41)	0.29	1.18 (0.87 – 1.62)
Anterior angle	**0.001**	1.21 (1.04 – 1.41)	**0.02**	1.21 (1.09 – 1.64)

Table 4: ROC curve analysis of calcaneal parameters in detecting male gender.

Variables	**Cut-point**	**Sensitivity (%)**	**Specificity (%)**	**PPV (%)**	**NPP (%)**	**AUC (%)**
Max. width	**51.5**	62.96%	85.19%	80.95%	69.7%	0.793
Body width	**39.6**	51.85%	96.3%	93.33%	66.67%	0.735
Max. length	**70.6**	88.89%	44.44%	61.54%	80%	0.697
Min. length	**61.3**	59.26%	81.48%	76.19%	66.67%	0.689
Height of cuboidea	**22.4**	44.44%	92.59%	85.71%	62.5%	0.726
Tuber angle	**41.5**	85.19%	44.44%	60.53%	75%	0.695
Anterior angle	**34.7**	74.07%	51.85%	60.61%	66.67%	0.698

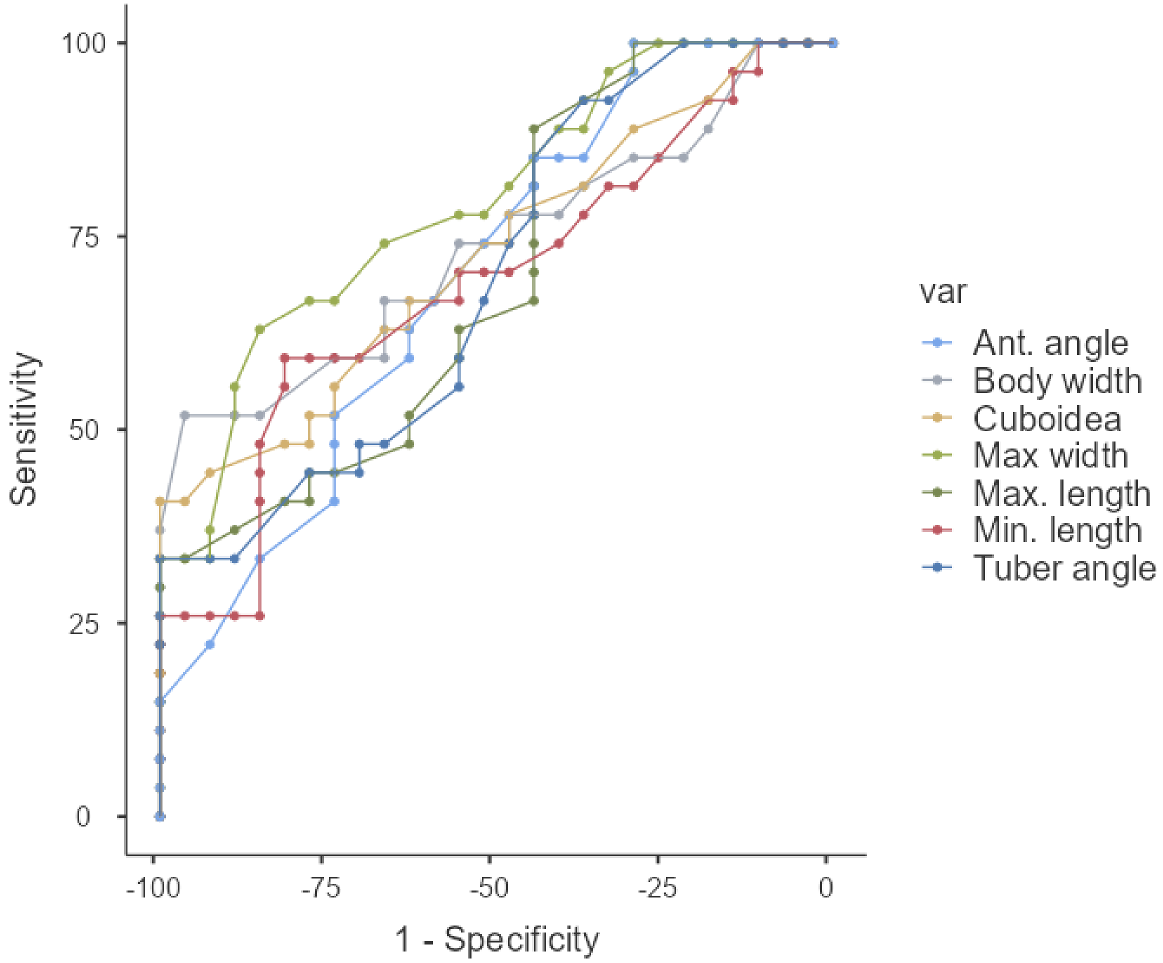

Fig. 5: ROC curve analysis of calcaneal parameters in detecting male gender

DISCUSSION

The calcaneal bone, the biggest of all foot bones, is crucial for sustaining and supporting an effective bipedal walk. It is part of the talocalcaneal/subtalar joint, which also includes the talus. This joint permit one's foot to move in both eversion and inversion. Calcaneal morphometric values are crucial for anatomy, diagnosis and therapy in orthopedic surgery, kinesiology as well as anthropological and forensic studies. The changes in the anatomical architecture of the calcaneus play a crucial role in the foot's dynamic, kinetic, and static properties (Kidd and Oxnard, 2002). The calcaneus is one of the bones used to determine gender and calculate stature. Furthermore, it is one of the bones employed in forensic sciences because it is a well-maintained bone (Otağ *et al.,* 2017).

Due to their sexual dimorphism and ability to withstand postmortem injury, foot bones can be used for gender determination Each one of the bone sizes can be used to accurately determine the sex, which varies among different races (Introna Jr *et al.,* 1997). In this study, we observed that both sexes differed considerably in all calcaneal measured diameters including maximum width, body width, maximum and minimum lengths, height of the facies cuboidea, and angular measurements (tuber and anterior angles) thus, they can be utilized to determine gender in the Egyptian population. However, the males' morphometric measurements were higher than the females'. This matches results of previous research within Iranian population reported by (Faress *et al.,* 2021, Tümer *et al.,* 2019, Koh *et al.,* 2024).

In this study, the males' morphometric measurements were higher than the females'. Nonetheless, morphometric values in numerous earlier investigations were seen to deviate from our morphometric findings for both males and females (Kim *et al.,* 2013, Uzuner *et al.,* 2016, Bidmos and Asala, 2003, Ceranoğlu *et al.,* 2024). It was believed that this discrepancy was caused by genetic variations (Uzuner *et al.,* 2016).

In the same context, calcaneal width measures in this study were 38.5 ± 3.45 in male and 35.7 ± 2.33 in female while they were 33.0 mm in females and 36.9 mm in males according to (Tümer *et al.,*2019) in Southeast Asian population. Also, Calcaneal maximal lengths reported in this study were 79.1 ± 5.9 in males and 73.9 ± 6.49 in females. These results deviate to some extent with a previous research on Iranian people that reported the values of maximal length were72.76± 9.69 in male and 84.74 ±5.36 in females (Introna *et al.,*1997).

Compared to the other assessed factors within this study using ROC curve analysis, the length and tuber angle variables exhibit better levels of accuracy for determining sex. This was similar to Ekizoglu *et al.* (2017) who found significant differences in calcaneal length across both sexes using computed tomography images (Ekizoglu *et al.,* 2017). In contrast to the previous mentioned observations (Bidmos and Asala, 2004), (Bidmos and Asala, 2003) and (Kim *et al.,* 2013) in their researches stated that Dorsal articular facet length, Dorsal articular facet breadth and Minimum breadth to be the top discriminators respectively. Genetics, routine behaviors, and size variations may all contribute to these variances. Future study should look at these connections.

In Turkish cadavers (Zeybek *et al.,* 2008), calcaneal length shows a high value for estimating gender but one variable was better than it that is Foot length. This agrees with the results of (Ceranoğlu *et al.,*2024) using lateral calcaneal radiographs. However, Gualdi-Rosso (2007) demonstrated that talus length was more efficient in determining sex over calcaneus length (Gualdi-Russo, 2007).

Conclusion

While length measures were shown to be a simple way to determine sex, there were no significant differences in measurements of angle across subjects. Imaging study of the calcaneus, supplemented by non-metric methods commonly utilized by forensic anthropologists, serves as an effective substitute in forensic anthropology and sciences.

Declarations:

Ethical Approval and Consent to Participate: The study protocol was approved by the Institutional review board of Zagazig university. The variables assessed, benefits and goals were all in accordance of declaration of Helsinki. IRB approved the study within the ethical guidelines as outlined in the declaration of Helsinki (Ethics committee approval numbered (822/5-Nov-2024).

Competing interests: The authors do not have any relevant financial or non-financial interests to report.

Availability of Data and Materials: All data generated or analyzed during this study are included in this published article.

Authors' Contributions: All authors contributed to the study's conception and design. [Nehal E. Refaay] and [Reham] prepared the materials, collected the data, and analyzed them. The original draft of the book was written by [Nehal Bahaa]. All authors reviewed and authorized the final manuscript.

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Acknowledgments: Special thanks to Zagazig university hospitals, Anatomy and radiology departments, Faculty of Medicine, Zagazig University. Many thanks to Scientific Medical Research Center

REFERENCES

Amuti, T., Muuthuri, N., Nichome, L., Ouko, I., Misiani, M., Olabu, B. & Ogeng'o, J. (2020). Morphometric dimensions of the calcaneus. *The Journal of Foot and Ankle Surgery,* 59,p.p :949-952. doi.org/10.1053/j.jfas.2019.09.040.

Anatomy, S. S. G. S. (2008). The anatomical basis of clinical practice. *London: Churchill Livingstone,* 40**,** 432.

doi.org/10. 1302/0301- 620X.91B7. 22719.

Bidmos, M. A. & Asala, S. A. (2003). Discriminant function sexing of the calcaneus of the South African whites. *Journal of Forensic Sciences,* 48, JFS2003104. DOI: 10.1520/JFS 2003104.

Bidmos, M. A. & Asala, S. A.(2004). Sexual dimorphism of the calcaneus of South African blacks. *Journal of Forensic Sciences,* 49, JFS2003254-5. https:// doi.org/10.1520/JFS2003254.

Buran, F., Can, I. O., Ekizoglu, O., Balci, A. & Guleryuz, H. 2018. Estimation of age and sex from bimastoid breadth with 3D computed tomography. *Romanian Journal of Legal Medicine,*26, 56-61.doi.org/10. 4323/ rjlm.2018.56

Ceranoĝlu, F. G., Ylmaz, M. T., Saygn, D. A. & Kadyoran, C.(2024). Distance Parameter Values of Calcaneus and their Performance for Gender Estimation. *Medical Records,* 6**,** p.p: 239-248. doi.org/10.37990/medr. 1419133.

Ekizoglu, O., Inci, E., Palabiyik, F. B., Can, I. O., Er, A., Bozdag, M., Kacmaz, I. E. & Kranioti, E. F. (2017). Sex estimation in a contemporary Turkish population based on CT scans of the calcaneus. *Forensic Science International,* 279**,** 310. doi.org/10. 1016/j.forsciint.2017.07.038

Faress, F., Ameri, M., Azizi, H., Shekofte, H. S. & Hosseini, R.(2021). Gender determination in adults using calcaneal diameters from lateral foot X-ray images in the Iranian population. *Medical Journal of the Islamic Republic of Iran,* 35 ,p.p: 76. doi: 10.47176/mjiri.35.76

Gualdi-Russo, E. (2007). Sex determination from the talus and calcaneus measurements. *Forensic Science International,* 171**,** p.p: 151-156. doi. org/10.1016/j.forsciint.2006.10.014

Introna JR, F., Di vella, G., Pietro Campobasso, C. & Dragone, M. (1997). Sex determination by discriminant analysis of calcanei measurements. *Journal of Forensic Sciences,* 42, p.p :725-728. doi.org/10. 1520/JFS14192J

Kidd, R. & Oxnard, C. (2002). Patterns of morphological discrimination in selected human tarsal elements. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists,* 117**,** p.p: 169-181. doi.org/10.1002/ajpa.20017

Kim, D.-I., Kim, Y.-S., Lee, U.-Y. & Han, S.-H. (2013). Sex determination from calcaneus in Korean using discriminant analysis. *Forensic Science International,* 228**,** 177. doi. org/10.1016/j.forsciint.2013.03.012

Koh, D., Tan, B., Mehta, K., Loh, J., Chong, L. R. & King, C. K. K. (2024). Morphometric analysis of the calcaneus in a Southeast Asian population. *Cureus,* 16. e58899. DOI: 10.7759/cureus.58899

Mahan, J., Damodar, D., Trapana, E., Barnhill, S., Nuno, A. U., Smyth, N. A., Aiyer, A. & Jose, J. (2020). Achilles tendon complex: The anatomy of its insertional footprint on the calcaneus and clinical implications. *Journal of Orthopaedics,* 17**,** 221-227. doi.org/ 10.1016/j.jor.2019.06.008

Otağ, İ., Tetiker, H., Taştemur, Y., Sabancoğuullar, V., Koşar, M. İ. & Çimen, M.(2017). Morphometric Measurements of Calcaneus; Boehler'sangle and bone length estimation. *Cumhuriyet Üniversitesi Fen Edebiyat Fakültesi Fen Bilimleri Dergisi,* 38**,**p.p: 256-263. doi.org/10. 17776/cumuscij.291995

Rohen, J. W., Yokochi, C. & Lutjen-DrecollR, E. 2002. *Color atlas of anatomy*, Lippincott Williams & Wilkins Maryland.

Sakaue, K. 2011. Sex assessment from the talus and calcaneus of Japanese.

Bulletin of the National Museum of Nature and Science,500, 35-48.

Scheuer, L.(2002). Application of osteology to forensic medicine. *Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists,* 15,p.p: 297-312. doi: 10.1002/ca. 10028

Schmutz, B., Lűthi, M., Schmutz-Leong, Y. K., Shulman, R. & Platt, S. (2021). Morphological analysis of Gissane's angle utilising a statistical shape model of the calcaneus. *Archives of Orthopaedic and Trauma Surgery,* 141,p.p: 937-945. DOI:10.1007/ s00402-020-03566-5

Scott, S., Ruengdit, S., Peckmann, T. R. & Mahakkanukrauh, P.(2017). Sex estimation from measurements of the calcaneus: Applications for personal identification in Thailand. *Forensic Science International,* 278, 405. doi. org/10.1016/j.forsciint.2017.06.035

Tűmer, N., Arbabi, V., Gielis, W. P., De jong, P. A., Weinans, H., Tuijthof, G. J. & Zadpoor, A. A. (2019). Three-dimensional analysis of shape variations and symmetry of the fibula, tibia, calcaneus and talus. *Journal of Anatomy,* 234, p.p: 132-144. doi: 10. 1111/joa.12900.

Uzuner, M. B., Geneci, F., Ocak, M., Bayram, P., Sancak, İ. T., Dolgun, A. & Sargon, M. F. (2016). Sex determination from the radiographic measurements of calcaneus. *Anatomy,* 10, p.p:200-204. doi:10.2399/ana.16.039.

Washburn, S. L. (1948). Sex differences in the pubic bone. *American Journal of Physical Anthropology,* 6,p.p:199-208. doi.org/10.1002/ajpa.1330060210.

Zeybek, G., Ergur, I. & Demiroglu, Z. (2008). Stature and gender estimation using foot measurements. Forensic Science International, 181, 54. doi.org/10. 1016/j.forsciint.2008.08.003