ORIGINAL RESEARCH

Morphometric Analysis of Sri Lankan Mastoid Processes and Its Application for in Gender Verification in Bioarcheology and Forensic Medicine

C Katupelella[1], S Ihalage[1], LG Rebeira[1], W Priyadarshani[1], S Alahakoon[2], EAST Edirisinghe[2], L Weerabhahu[2], S Bowatte[3], H Dissanayake[2], SG Yasawardene[2]

[1]*Department of Anatomy, Faculty of Medicine, Wayamba University of Sri Lanka*
[2]*Department of Anatomy, Faculty of Medical Sciences, University of Sri Jayewardenepura*
[3]*Department of Medicine, Faculty of Medicine, Wayamba University of Sri Lanka*

Abstract

Objective: The present study aimed to determine sex from morphometry of the mastoid process and surface area of mastoid triangle among Sri Lankans.

Methods: The research was conducted on 60 dry skulls collected from three locations in Sri Lanka. Eight morphometric parameters of the mastoid process were measured bilaterally and the surface area of the mastoid triangle, which is formed between the porion, mastoidale, and asterion was calculated. Statistical analysis was performed using SPSS 23 software. An independent t-test was applied to evaluate the significance of sex-based differences for each parameter.

Results: The findings indicated that the mean measurements were consistently larger in males compared to females for all parameters measured bilaterally. The independent t-test revealed significant sex differences in mastoid height 1, mastoid height 2, mastoid height 3, mastoid length 1, porion-mastoidale distance, and asterion-mastoidale distance. No significant differences were found for mastoid width and mastoid length 2. Mean surface area of the mastoid triangle was significantly greater in males than in females on both sides.

Conclusion: These morphometric features of the mastoid process and mastoid triangle surface area could be effectively used for sex determination in the Sri Lankan population.

Keywords: Mastoid Process; Morphometry; Gender Dimorphism; Bioarcheology; Forensic Medicine

DOI: https://doi.org/10.4038/slaj.v10iI.303

Sri Lanka Anatomy Journal 2026; 10(I): 65–76

Corresponding author

EAST Edirisinghe
email: *edirisinghe@sjp.ac.lk*
https://orcid.org/0000-0002-8360-5157

Introduction

Determining the sex of skeletal remains is a key objective in anthropology and archaeological research (1, 2). Various techniques have been employed for this purpose, including DNA analysis (3, 4), forensic odontology (3, 5), and the examination of morphological and morphometric features of human bones (6, 7). These methods typically leverage sexual dimorphism, the physical differences between male and female skeletons, found in most human bones (7). Gender specific morphology and morphometry of several human bones are used to decide the sex of a deceased person (8).

The accuracy of sex determination depends on the completeness and the condition of the skeleton (9). However, forensic experts and anthropologists often face challenges when dealing with incomplete or fragmented remains (4). Among skeletal structures, the pelvis and skull exhibit the most significant sexual dimorphism in adult (9). If the pelvic bones, which are the most reliable for sex determination, are unavailable or severely fragmented, the skull, regarded as the second-best indicator, becomes the primary focus (10). Bass highlighted that the skull is the second-best skeletal part that can be used for human sex determination in skeletal remains (11). Consistently, the literature recognizes the skull and its fragments as a reliable alternative for determining sex in cases involving incomplete skeletal remains (12, 13).

The mastoid process of the temporal bone is a prominent, downward, and forward-pointing projection situated posterolaterally to the styloid process and posterior to the external acoustic meatus (14). It has compact bone, making it highly durable and likely to persist longer than other parts of the skull. Due to its robust nature and frequent presence in skeletal remains, the mastoid process is often available for analysis. Its sexually dimorphic characteristics and commonality in skeletal remains make it a valuable feature for sex determination in forensic and archaeological studies (15).

Different studies have proved that the mastoid process shows morphological and morphometric gender variations among different ethnic groups around the globe. A study conducted among North Indians indicated that morphometric characteristics showed significant sexual dimorphism and they are different from the other populations in India. The accuracy of sex determination by using individual variables ranged from 68.1% to 75.4% in their study (16). A Japanese study showed that mastoid length, width, and height were significantly different among genders and revealed that using a single variable for sex determination achieved an accuracy of over 80% (17). Another study in Thailand focused on human sex determination through mastoid process measurements and reported an accuracy ranging from 67% to 76.9% (1).

Studies have shown that the morphology and morphometry of the mastoid process differ significantly across ethnic groups worldwide and are strongly associated with gender. However, a thorough review of the literature revealed a lack of published data regarding the morphometry and morphology of the mastoid process in Sri Lankans, as well as its gender-specific characteristics. To address this gap, this study was conducted to investigate the morphometric variations of the mastoid process in male and female Sri Lankans and identify the parameters most useful for gender determination.

Methods

The study utilized 60 dry human skulls with intact mastoid processes. These were collected from three institutions located in different regions of Sri Lanka: 25 skulls from the Department of Anatomy, Faculty of Medicine, University of Peradeniya (Central region), 20 skulls from the Department of Anatomy, Faculty of Medicine, Wayamba University of Sri Lanka (Northwestern region), and 15 skulls from the Department of Basic Principles, Gampaha Wickramarachchi University (Western region).

The gender of each skull was determined using the documented information of the donors prior to measurement and was later cross-checked using morphological characteristics specific to sex determination of the mastoid process and thereafter, full skull (4). The age of each skull was estimated by examining the dental attrition patterns of the upper molar teeth, following the standard attrition patterns outlined by Bass in 2005 (4).

Porion (a critical anthropometric and cephalometric landmark located at the highest point of the bony external auditory meatus on the skull.)(18), asterion (the junction of the lambdoid, parietomastoid, and occipitomastoid sutures) (19), and mastoidale (the craniometrics point located at the most inferior tip of the mastoid process of the temporal bone, situated behind the ear)(20) locations are given in Figure 1 and were identified in each selected skull to the study as the anatomical reference points to take the measurements.

The following measurements of the mastoid process were taken bilaterally, relying on the anatomical landmarks described by Nagoka et al. (2008) (17) and Çalışkan et al. (2020) (14). Using a digital vernier caliper, the parameters measured included mastoid height, mastoid width, mastoid length, porion-mastoidale distance (po-ms), and asterion-mastoidale distance (ast-ms).

Mastoid height was measured in three distinct ways: distance from mastoidale to the mid-point of the imaginary line joining porion and the posterior end of the incisura mastoidea (MH1), perpendicular distance from mastoidale to the Frankfort plane (MH2), distance from mastoidale to the mid-point of the imaginary line joining the posterior end of incisura mastoidea and the closest point on the posterior border of the external auditory canal (MH3) (Figure 2).

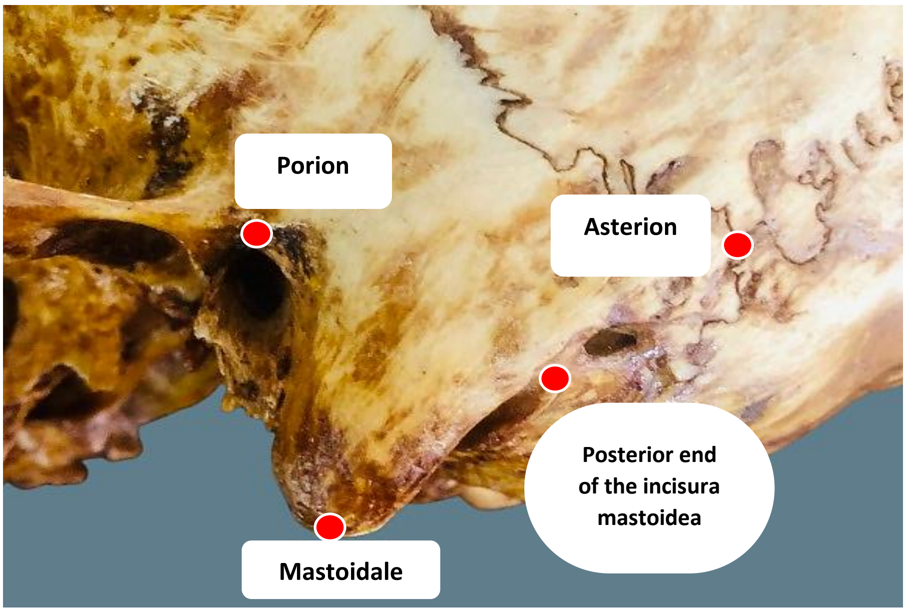

Figure 1: Anatomical reference points surrounding the mastoid process

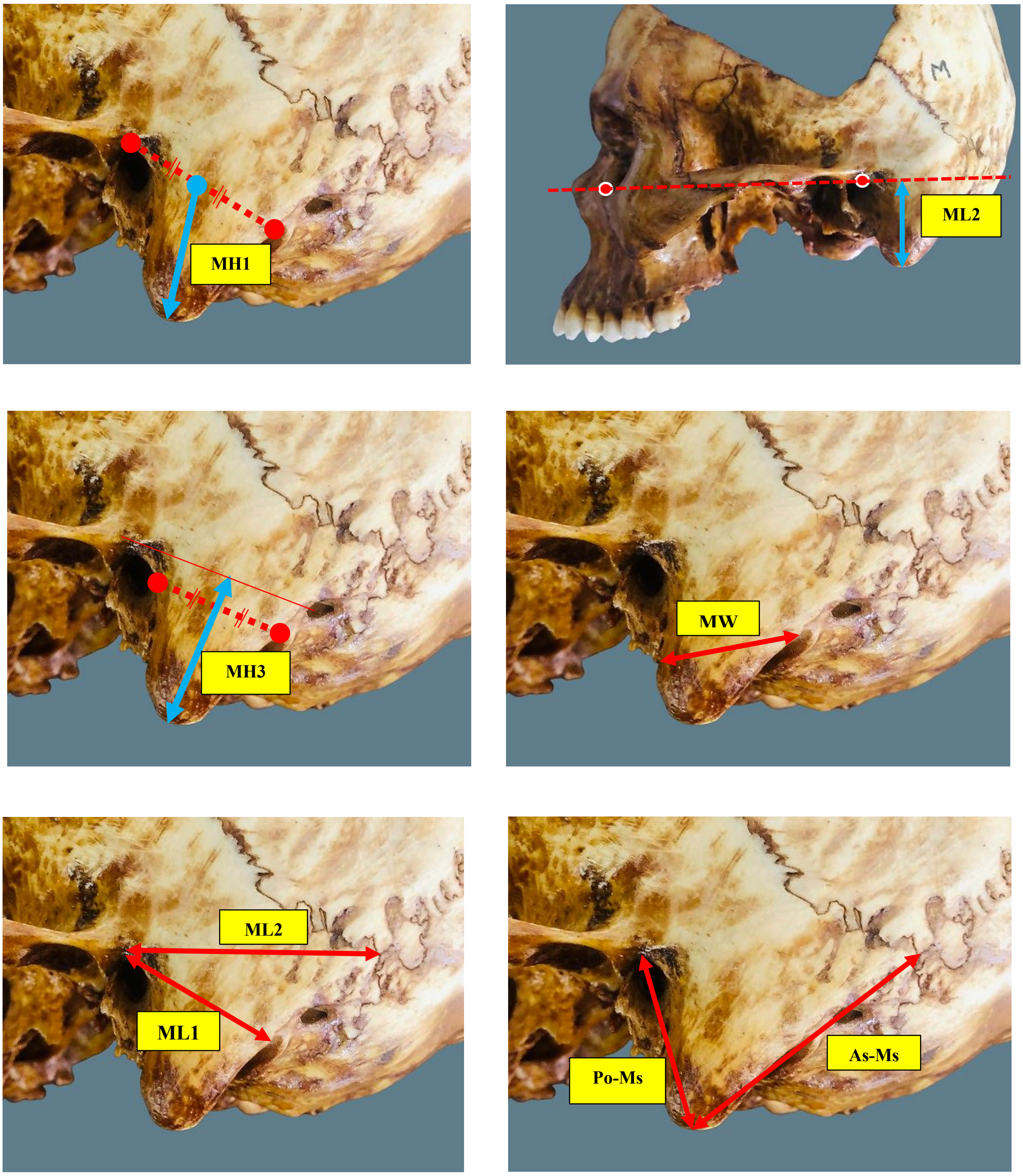

Figure 2: The anatomical landmarks for mastoid process measurements. MH1 - distance from mastoidale to the mid-point of the imaginary line joining porion and the posterior end of the incisura mastoidea, MH2 - perpendicular distance from mastoidale to the Frankfort plane, MH3- distance from mastoidale to the mid-point of the imaginary line joining the posterior end of incisura mastoidea and the closest point on the posterior border of the external auditory canal mastoid width, MW - the posterior end of the incisura mastoidea to the closest point on the posterior edge of the external auditory meatus, ML1 - distance from porion to the posterior end of incisura mastoidea , ML2 - distance from porion to asterion

Mastoid width (MW) was measured from the posterior end of the incisura mastoidea to the closest point on the posterior edge of the external auditory meatus. Two different mastoid lengths were taken; distance from porion to the posterior end of incisura mastoidea (ML1), distance from porion to asterion (ML2). Eight measurements were taken from each mastoid process for this study. By using measurements of the dimensions of porion-mastoidale distance, asterion-mastoidale distance and porion-asterion distance (ML2) the surface area for mastoid triangle bilaterally was determined by using Heron's formula.

Data analysis was done using SPSS software (version 23.0). Mean and standard deviation for each measurement in right and left sides was obtained for males and females separately through statistical analysis. Thereafter, an independent t-test was done in order to analyze the significance of the gender difference of each measurement.

Results

The number of skulls studied in this project was 60 and 29 male skulls and 31 female kulls were identified among them according to observed gender determination morphological characteristics. The ages ranged from 60 – 80 years with reference to the studied attrition pattern of maxillary molar teeth available in the skulls.

The results showed that the means of all mastoid measurements were higher in males than females on both sides. The independent samples t-test showed significant differences in gender in most of the parameters bilaterally (Table 1). Specifically, males exhibited significantly greater mean values for right and left mastoid height 1, mastoid height 2, mastoid height 3, mastoid length 1, porion-mastoidale distance, and asterion-mastoidale distance compared to females. However, no significant gender differences were seen in mastoid width and mastoid length 2 on either side.

The mean surface area of the mastoid triangle was significantly larger in males than in females bilaterally ($P< 0.000$) (Table 2).

Discussion

Metrical analysis of human skeletal remains is preferred over non-metric analysis due to its objectivity and significant contribution to sex determination (18). In bioarcheology and forensic medicine, the mastoid process is an essential feature for determining biological sex. The size and dimensions of mastoid process are assessed using osteometric measurements and statistical methods (such discriminant function analysis) in order to determine gender of the skeletal remains as male or female, which is an essential initial step in identifying the individual (1, 17). The mastoid process is considered to be one of the most dimorphic features of the skull. Importantly, its position at the base of the skull makes it relatively protected and often less prone to damage or fragmentation than the pelvis or other cranial features, making it valuable even in cases where the skull is incomplete or fragmented (8). The size and shape of the mastoid process can show variations across different populations, providing supplementary information in estimating the individual's geographic ancestry. Given the absence of published data on mastoid process measurements and their gender-specific variations in the Sri Lankan population, this study focused on morphometric analysis of the mastoid process using adult dry skulls from Sri Lankans.

Table 1: Mean, ranges of values of bilateral mastoid measurements of each gender and calculated P values of each measurement among gender

Measurement	Gender	Mean ± SD (mm)	Range (Min-Max) (mm)	p value
Mastoid height-1 (Right)	Male	24.81 ± 2.343	21 – 28	0.000
	Female	21.11 ± 2.958	15 – 26	
Mastoid height-1 (Left)	Male	25.15 ± 2.777	21 – 31	0.000
	Female	21.38 ± 1.949	18 – 24	
Mastoid height-2 (Right)	Male	28.02 ± 3.032	22 – 35	0.002
	Female	24.53 ± 3.515	17 – 31	
Mastoid height-2 (Left)	Male	29.08 ± 2.957	25 – 37	0.000
	Female	25.00 ± 2.812	19 – 30	
Mastoid height-3 (Right)	Male	19.49 ± 3.081	13 – 27	0.004
	Female	16.54 ± 2.484	12 – 20	
Mastoid height-3 (Left)	Male	20.20 ± 2.984	13 – 25	0.001
	Female	17.23 ± 1.733	14 – 20	
Mastoid width (Right)	Male	16.91 ± 2.345	10 – 21	0.200
	Female	15.92 ± 2.318	13 – 21	
Mastoid width (Left)	Male	16.39 ± 1.880	14 – 21	0.057
	Female	15.16 ± 2.079	11 – 25	
Mastoid length-1 (Right)	Male	32.20 ± 2.908	26 – 39	0.014
	Female	29.09 ± 4.741	22 – 36	
Mastoid length-1 (Left)	Male	31.84 ± 2.785	24 – 37	0.001
	Female	28.37 ± 3.016	23 – 34	
Mastoid length-2 (Right)	Male	42.56 ± 4.079	35 – 50	0.148
	Female	40.61 ± 3.830	34 – 47	
Mastoid length-2 (Left)	Male	42.53 ± 4.516	33 – 51	0.076
	Female	39.66 ± 5.308	33 – 53	
Porion-mastoidale distance (Right)	Male	31.04 ± 2.587	25 – 35	0.000
	Female	27.18 ± 3.258	21 – 33	
Porion-mastoidale distance (Left)	Male	31.20 ± 2.871	23 – 36	0.000
	Female	27.56 ± 2.887	21 – 32	
Asterion-mastoidale distance (Right)	Male	48.04 ± 5.640	38 – 58	0.003
	Female	42.83 ± 3.991	37 – 49	
Asterion-mastoidale distance (Left)	Male	47.74 ± 4.821	38 – 57	0.000
	Female	40.64 ± 4.853	32 - 50	

Table 2: The mean, ranges of values of bilateral surface area of mastoid triangle of each gender and calculated P value for each side among gender

Measurement	Gender	Mean ± SD (mm)	Range (Min-Max) (mm)	p value
Mastoid triangle surface area (R)	Male	620.39 ± 92.658	426.98 - 834.26	0.000
	Female	560.90 ± 93.743	384.11 - 739.59	
Mastoid triangle surface area (L)	Male	609.99 ±100.873	405.99 - 858.36	0.000
	Female	561.57 ± 109.589	420.24 - 796.25	

Table 3: Current literature on the morphometry of the mastoid process

Article	Sample size	Study population	Measurements	Male		Female		Key findings (significant differences)
				Right (mm)	Left (mm)	Right (mm)	Left (mm)	
Paiva & sagre, 2003 [8]	60 skulls (30 males, 30 females)	Brazil	Area of mastoid triangle	752.1	753.22	608.7	602.54	Significant gender difference in right and left mastoid triangular area
Kemkes & göbel, 2006 [18]	97 skulls (25 females, 72 males)	German forensic sample	Po-ms	30.9 ± 3.1	30.9 ± 2.6	28.9 ± 3.6	29.2 ± 3.4	Significant difference in right and left po-ms and mastoid triangular area in portuguese males significant gender difference in all the measurements expect ms-ast in German sample
			Ast-ms	50.5 ± 4.8	50.2 ± 4.0	49.4 ± 5.5	49.4 ± 5.1	
			Po-ast	48.6 ± 3.3	48.4 ± 3.5	46.3 ± 3.7	46.2 ± 4.4	
			Area of mastoid triangle	717.6 ± 94.5	716.7 ± 81.1	655.9 ± 129.1	659.4 ± 123.3	
	100 skulls (50 females, 50 males)	Portuguese cemetery sample	Po-ms	31.5 ± 3.7	30.9 ± 3.7	28.4 ± 2.6	27.8 ± 2.8	
			Ast-ms	49.5 ± 5.2	49.1 ± 4.9	45.8 ± 4.6	46.0 ± 4.3	
			Po-ast	47.7 ± 3.8	47.1 ± 3.3	45.1 ± 2.9	44.9 ± 3.6	
			Area of mastoid triangle	718.9 ± 118.3	699.9 ± 115.8	609.5 ± 85.7	599.5 ± 91.9	
Galdames et al., 2008 [19]	81 skulls (50 males, 31 females)	Brazil	Po-ms	30.72 ± 2.73	29.22 ± 2.73	27.55 ± 2.78	29.74 ± 4.14	Significant gender difference in right po-ms and right mastoid triangular area
			Ast-ms	50.21 ± 4.96	50.22 ± 4.95	48.34 ± 3.87	50.17 ± 5.18	
			Po-ast	47.45 ± 4.43	47.51 ± 3.46	46.74 ± 3.30	47.53 ± 3.80	
			Area of mastoid triangle	703.34 ± 94.31	674.45 ± 92.25	624.08 ± 86.46	685.64 ± 115.93	
Nagaoka et al., 2008 [17]	22 males and 26 females from yuigahama-minami	Human skeletal remains from the yuigahama-minami site	Mastoid height 1		25.28 ± 2.12		20.9 ± 2.4	The accuracy of sex determination using a single variable was over 80%. The accuracy reached 82-92% when
			Mastoid height 2		31.91 ± 2.47		28.3 ± 3.0	
			Mastoid height 3		28.23 ± 2.18		24.4 ± 2.6	

			Mastoid width	12.96 ± 1.74	10.0 ± 1.2	two variables were combined (mastoid height and width).
			Mastoid length 1	35.60 ± 1.97	32.5 ± 2.5	
			Mastoid length 2 (po-ast)	49.30 ± 2.64	47.0 ± 2.9	
	28 males and 11 females from hitotsubashi	Human skeletal remains from the hitotsubashi site	Mastoid height 1	24.29 ± 2.49	20.3 ± 2.9	
			Mastoid height 2	31.80 ± 3.53	26.8 ± 2.2	
			Mastoid height 3	27.96 ± 3.36	23.1 ± 2.6	
			Mastoid width	11.94 ± 1.37	9.4 ± 1.0	
			Mastoid length 1	33.95 ± 3.21	31.2 ± 1.7	
			Mastoid length 2 (po-ast)	48.80 ± 4.05	47.0 ± 2.1	
Saini et al., 2012 [16]	138 adult skulls (104 males, 34 females)	North indians	Mastoid length	35.832 ± 3.556	31.869 ± 3.326	All the 08 parameters showed significant sexual dimorphism. Posterior end of incisura mastoidea-depression of suprameatal triangle measurement was having the highest predictive accuracy of sex determination (82.6%).
			Mastoid breadth	25.582 ± 1.896	22..771 ± 2.374	
			Po-ast	47.894 ± 3.173	44.696 ± 3.756	
			Posterior end of incisura mastoidea-depression of suprameatal triangle (peim-dsmt)	28.022 ± 2.418	24.952 ± 2.410	
			Posterior end of incisura mastoidea-porion (peim-po)	35.585 ± 2.693	31.685 ± 3.100	
			Asterion-depression of suprameatal	41.049 ±	38.255 ± 3.522	

			triangle (ast-dsmt)		3.011			
			Ms-ast		47.837 ± 4.068		43.002 ± 4.324	
			Po-ms		31.775 ± 3.076		27.987 ± 3.471	
Manoonpol & plakornkul, 2012 [1]	100 skulls (60 males, 40 females)	Thais	Po-ms	35.05 ± 4.02	33.41 ± 3.82	31.21 ± 2.90	30.42 ± 5.37	All the linear measurements and mastoid triangular area were significantly higher among males compared to females. The best dimension to determine sex among thais was ms-ast (76.90%).
			Ast-ms	57.16 ± 4.57	57.03 ± 4.55	52.15 ± 4.00	52.30 ± 4.64	
			Po-ast	53.52 ± 4.37	53.00 ± 3.86	49.64 ± 3.35	49.18 ± 5.08	
			Area of mastoid triangle	912.70 ± 140.78	867.75 ± 135.28	448.30 ± 119.50	404.94 ± 133.30	
Çalişkan et al., 2020 [14]	20 skulls, (unknown gender)	Türkiye	Ast-ms	Right – 5.00 ± 0.65 left – 4.79 ± 0.53				Significant difference in ms-ast in right and left sides
			Po-ast	Right – 4.43 ± 0.47 left – 4.45 ± 0.47				
			Po-ms	Right – 2.87 ± 0.47 left – 2.79 ± 0.39				

Among the measurements evaluated, mastoid height 1, mastoid height 2, mastoid height 3, mastoid length 1, porion-mastoidale distance, and asterion-mastoidale distance were significantly greater in males compared to females on both sides (Table 1). Although mastoid width and mastoid length 2 were also higher in males than females bilaterally, these differences were not statistically significant. There was a significant bilateral sexual dimorphism in the surface of area of the mastoid triangle where males exhibited comparatively higher values compared to females.

The morphometry of the mastoid process has been evaluated across various populations. Table 3 depicts a comprehensive summary of literature regarding the morphometry of mastoid process across different population in the world. In the present study, the surface area of the mastoid triangle was found to be larger in males than in females on both sides and this finding is consistent with the findings reported by Paiva and Segre (2003) in a Brazilian population (8). According to the present study, the right mastoid triangle measured 620.39 ± 92.658 mm² in males and 560.90 ± 93.743 mm² in females, while the left side measured 609.99 ± 100.873 mm² in males and 561.57 ± 109.589 mm² in females. Although the mean values in the current st udy were generally lower than those reported by Paiva and Segre (752.10 mm² in males vs. 608.70 mm² in females on the right; 753.22 mm² in males vs. 602.54 mm² in females on the left), both studies demonstrate a consistent pattern of sexual dimorphism, with males exhibiting larger mastoid triangle areas than females. This reinforces the potential utility of the mastoid triangle area as a morphometric indicator for sex estimation, though population-specific variations must be considered when applying these findings in forensic contexts.

In the present study, significant gender differences were observed in the porion–mastoidale (po–ms), asterion–mastoidale (ast–ms) distances and surface area of the mastoid triangle on both right and left sides, with males exhibiting higher values than females. However, the porion–asterion (po–ast), referred to as mastoid length 2, did not show a statistically significant difference between sexes on either side. This suggests that po–ms, ast–ms and the surface area of the mastoid triangle are reliable indicators of sexual dimorphism in the present population. In contrast, Kemkes and Göbel (2006), who investigated German forensic and Portuguese cemetery samples, reported significant gender differences in all parameters except for ast–ms in the German sample. The difference between studies highlights the influence of population-specific variation in cranial morphology (21).

Galdames et al. has investigated po-ms, ast-ms, po-ast and the surface area of mastoid triangle in a Brazilian sample. In this study, a significant gender difference was observed only in right po-ms and right mastoid triangular area. These results highly contrast with that of the present study. In Galdames et al., po–ms and mastoid triangular area showed asymmetrical dimorphism favoring the right side, whereas in the current study po–ms were bilaterally significant (22).

A Japanese study has measured mastoid height 1, mastoid height 2, mastoid height 3, mastoid width, mastoid length 1, and mastoid length 2 only on the left side of the crania in two samples of skeletal remains excavated from Yuigahama-minami and Hitotsubashi sites.Similar to that of the present study, all the measured variables in the Japanese study show reported higher values among males compared to females in both populations. Significant sexual dimorphism has been reported in all the variables except mastoid length 1 and mastoid length 2 in Hitotsubashi sample. When comparing the mean values of Japanese measurements with those from the present study, mastoid height 2, mastoid height 3, mastoid length 1, and mastoid length 2 were greater in both male and female Japanese samples than in their Sri Lankan counterparts. However, Sri Lankans exhibited higher mean values for mastoid width than those reported in the Japanese study. These differences highlight the population-specific variation in mastoid measurements across different regions. Further they have assessed the accuracy of sex determination using a single variable as well as a combination of two variables. The accuracy was over 80% with a single variable and it was 82-925 when mastoid height and width was combined (17).

Saini et al. (2012) has studied the morphometry of the left mastoid process in North Indian adult skulls in terms of 08 parameters (16). Only the distances between **po-ast, ms-ast**, and **po-ms** were measured in a manner consistent with the present study, utilizing the same anatomical reference points. All these 03 parameters have shown a significant sexual dimorphism. Mean values for all these three measurements are slightly higher among North Indians compared to that of Sri Lankans.

A 2012 study in Thailand evaluated porion-mastoidale, mastoidale-asterion, and porion-asterion distances bilaterally, which were comparable to the parameters measured in this study. That study mentioned that all measurements were significantly larger in males than females. A comparison of the mean values from the that study with those from the current study revealed that Thai mastoid processes are generally larger than Sri Lankan mastoid processes (1).

In conclusion the findings of this study demonstrate that most of the morphometric parameters of the mastoid process, as well as the surface area of the mastoid triangle, show significant gender-based differences. Additionally, the observed values for the Sri Lankan population differ from those reported for other ethnic groups globally. In practical applications, these morphometric characteristics of the mastoid process and the surface area of the mastoid triangle can be effectively utilized for sex determination of Sri Lankans in bioarcheology and forensic medicine.

Acknowledgements

The authors sincerely thank those who donated their bodies to science so that anatomical research and teaching could be performed. Results from such research can potentially increase scientific knowledge and can improve patient care. Therefore, these donors and their families deserve our highest respect.

References

1. Manoonpol C, Plakornkul V. Sex determination using mastoid process measurement in Thais. J Med Assoc Thai. 2012; 95(3):423–9.

2. Steyn M, İşcan MY. Metric sex determination from the pelvis in modern Greeks. Forensic Science International [Internet]. 2008 [accessed 2025 Nov 17]; 179(1):86.e1-86.e6. Available from: https://www.sciencedirect.com/science/article/pii/S0379073808002041

3. Stewart NA, Gerlach RF, Gowland RL, Gron KJ, Montgomery J. Sex determination of human remains from peptides in tooth enamel. Proc Natl Acad Sci USA [Internet]. 2017 [cited 2025 Nov 17]; 114(52):13649–54. Available from: https://pnas.org/doi/full/10.1073/pnas.1714926115

4. Stone AC, Milner GR, Pääbo S, Stoneking M. Sex determination of ancient human skeletons using DNA. Am J Phys Anthropol [Internet]. 1996 [cited 2025 Nov 17]; 99(2):231–8. Available from: https://onlinelibrary.wiley.com/doi/10.1002/(SICI)1096-8644(199602)99:2<231::AID-AJPA1>3.0.CO;2-1

5. Nagare SP, Chaudhari RS, Birangane RS, Parkarwar PC. Sex determination in forensic identification, a review. Journal of Forensic Dental Sciences [Internet]. 2018 [cited 2025 Nov 17]; 10(2):61. Available from: https://journals.lww.com/jfds/fulltext/2018/100

20/sex_determination_in_forensic_identification,_a.2.aspx

6. Bidmos MA, Gib bon VE, Strkalj G. Recent advances in sex identification of human skeletal remains in South Africa : review article. South African Journal of Science [Internet]. Academy of Science for South Africa (ASSAf); 2010 [cited 2025 Nov 17]; 106(11):1–6. Available from: https://journals.co.za/doi/abs/10.10520/EJC96985

7. Lucena-dos-Santos ERS, Albuquerque PPFD, Albuquerque PVD, Oliveira BDRD, Caiaffo V. Determination of Sex Based on the Morphometric Evaluation of the Proximal Tibia. Int J Morphol [Internet]. 2018 [cited 2025 Nov 17]; 36(1):104–8. Available from: http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0717-95022018000100104&lng=en&nrm=iso&tlng=en

8. Paiva LASD, Segre M. Sexing the human skull through the mastoid process. Rev Hosp Clin [Internet]. 2003 [cited 2025 Nov 17]; 58(1):15–20. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0041-87812003000100004&lng=en&tlng=en.

9. G. V, Gowri S.R. M, J. A. Sex Determination of Human Mandible Using Metrical Parameters. J Clin Diagn Res [Internet]. 2013 [cited 2025 Nov 17]; 7(12):2671–3. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC3919368/

10. Curate F. The Estimation of Sex of Human Skeletal Remains in the Portuguese Identified Collections: History and Prospects. Forensic Sciences [Internet]. Multidisciplinary Digital Publishing Institute; 2022 [cited 2025 Nov 17]; 2(1):272–86. Available from: https://www.mdpi.com/2673-6756/2/1/21

11. Bass WM. Human osteology: a laboratory and field manual. 5. ed. Columbia, Mo: Missouri Archaeological Society; 2005.

12. Byers SN, Juarez CA. Introduction to Forensic Anthropology. 6th ed. New York: Routledge; 2023.

13. Pickering RB, Bachman D. The Use of Forensic Anthropology. CRC Press; 2009.

14. Çalişkan S, Akkaşoğlu S, Sargon MF, DemiRyürek MD. Mastoid process morphometry on dry skulls. Kırıkkale Üniversitesi Tıp Fakültesi Dergisi [Internet]. 2020 [cited 2025 Nov 17]; 22(1):58–63. Available from: http://dergipark.org.tr/en/doi/10.24938/kutfd.649170

15. Petaros A, Sholts SB, Slaus M, Bosnar A, Wärmländer SKTS. Evaluating sexual dimorphism in the human mastoid process: A viewpoint on the methodology. Clin Anat [Internet]. 2015 [cited 2025 Nov 17]; 28(5):593–601. Available from: https://onlinelibrary.wiley.com/doi/10.1002/ca.22545

16. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK. Sex Estimation from the Mastoid Process Among North Indians*. J Forensic Sci [Internet]. 2012 [cited 2025 Nov 17]; 57(2):434–9. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1556-4029.2011.01966.x

17. Nagaoka T, Shizushima A, Sawada J, Tomo S, Hoshino K, Sato H, et al. Sex determination using mastoid process measurements: standards for Japanese human skeletons of the medieval and early modern periods. AS [Internet]. 2008 [cited 2025 Nov 17]; 116(2):105–13. Available from: http://www.jstage.jst.go.jp/article/ase/116/2/116_070605/_article

18. Choi JW, Jung SY, Kim H-J, Lee S-H. Positional symmetry of porion and external auditory meatus in facial asymmetry. Maxillofac Plast Reconstr Surg [Internet]. 2015 [cited 2026 Feb 8]; 37(1):33. Available from: http://www.jkamprs.com/content/37/1/33