Journal of Morphological Sciences
J Morphol Sci
Brazilian Society of Anatomy

Original Article
J Morphol Sci 2023;40:278 -284

Accuracy of the Osteometric of the Mastoid Process for Sex Assessment in Human Skull Remains in South Indian Population and its Comparison with Other Regions of India

Hosapatna Mamatha[1], Kumar MR Bhat[2], Vishwanath Managuli[3], Lokadolalu Chandrachar Prasanna[4]

[1]Additional Professor, Department of Anatomy, Kasturba Medical College, Manipal Academy of Higher Education, Manipal-576104, Karnataka
[2]Professor & Chair, Department of Anatomy, Ras Al Khaimah College of Medical Sciences, RAK Medical & Health Sciences University, Ras Al Khaimah, UAE
[3]Assistant Professor (Selection Grade), Department of Mechanical Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal-576104, Karnataka
[4]Professor, Department of Anatomy, Kasturba Medical College, Manipal Academy of Higher Education, Manipal-576104, Karnataka

Disclose and conflicts of interest: none to be declared by all authors

ABSTRACT
Introduction: the mastoid area is one of the slowest developing regions of the cranium and appears late. A high degree of sexual dimorphism has been reported in adulthood.
Aim and Objective: this study focuses on providing an accurate and applicable method to determine the sexual dimorphism of the mastoid process by using readily available resources even in poorly preserved skull bones.
Material and Methods: a total of 100 mastoid processes (25 males and 25 female's skull bones) were segregated by two senior anatomists with through knowledge in anthropometric study. Inclusion and exclusion criteria were defined, and various mastoid parameters were measured as per the standard literature.
Results: in case of males the width, height, PA, MA, and PM measurements were higher on the right side than left. Whereas the length of the mastoid process in females was found to be more on the left side by a few millimeters. Also, in females the values were almost equal on the left and right side for all the above parameters.
Conclusion: it can be possible to determine the sex of the person whose identity is unknown only if we are aware of the nationality and race of the individual.
Keywords: Osteometry; Mastoid process; Sex determination; Skull; Craniometry.

Introduction

The human skeleton is made up of calcified hard tissue and can withstand extreme conditions. Estimation of sex is easy if all the bones of the skeleton are available[1]. However, in cases of natural disaster, explosions and crashes it's inevitable to find a suitable method for sex determination of residual bone fragments[1,2].

According to Krogman, the accuracy in sexing the adult skeletal remains is 100% when the entire skeleton is present. The accuracy varies with certain individual bones like pelvis (95%), skull (92%), pelvis and skull together (98%), long bones (80%), and long bones along with pelvis (98%). This demonstrates that the skeleton, pelvis, and skulls were used predominantly for anthropometric examinations[2, 3,4].

The petrous portion of the temporal bone is usually preserved in case of burning due to its compact nature and its protected position at the base of the skull. Thus, this anatomical region is favorable for sex determination due to its craniometric characteristics in forensic anthropology[5].

The mastoid area is one of the slowest developing regions of the cranium and appears late. A high degree of sexual dimorphism has been reported in adulthood[6].

Various methods have been proposed by researchers and anthropologists to determine the shape and size of the mastoid process [7,8]. It was reported that the Porion - Mastoidale distance had the highest prediction capacity followed by the mastoid height and width. The values obtained for these parameters have wide differences among various authors due to the presence of the wormian bones, position of asterion, and the complex nature of lambdoid suture. In cases of severe malnutrition, the mastoid process was observed to be a good indicator for sex determination with an accuracy of 87.3%[9].

This study focuses on providing an accurate and applicable method to determine the sexual dimorphism of the mastoid process by using readily available resources even in poorly preserved skull bones. Thus, authors opine that the combined and appropriate mastoid parameters is a must for reliable sex determination.

DOI: 10.51929/jms.40.278.2023
ISSN 2177-0298

Material and Methods

Materials: A total of 100 mastoid processes (25 males and 25 female's skull bones) were segregated by two senior anatomists with through knowledge in anthropometric study.

Inclusion & Exclusion criterion: Fully ossified skulls of mature individuals, which had no destruction of the mastoid region or absence of metopic bone in the region of the craniometrics points were chosen for the study. The skulls that presented trauma, evidence of deformities either partial or even to one of the below mentioned craniometrics points were excluded.

Methodology: Since the mastoid notch forms a variable reference point, this point was marked by a single author on both sides of the skull, and measurements were taken with skull in Frankfurt plane (Figure 1) and measured by using digital calipers to avoid error. The craniometric points (porion- Point on the upper margin of the external acoustic meatus, mastoidale- Lowest point of the mastoid process, and asterion- A point on the side of the skull corresponding to the posterior end of the parietomastoid suture) were identified on each skull, marked and the below-mentioned parameters were measured as shown in the Figure 2 and 3.

1. Mastoid length (L2): Distance between the porion to the asterion
2. Mastoid width (W) at its base: Distance between the mastoid incisura to the corresponding level on the external surface
3. Mastoid height (H2): Distance between a point on the Frankfort horizontal plane vertically downwards to the tip of the mastoid process
4. Porion – Mastoidale length (PM): Distance between the porion to the mastoidale
5. Mastoidale – Asterion length (MA): Distance between the mastoidale to the asterion
6. Porion – Asterion length (PA): Distance between the porion to the asterion

The mastoid triangle area (A) was calculated using Heron's formula[10.]

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

The semi-perimeter (s) of the mastoid triangle was calculated with the length of the PM (a), MA(b), and PA(c).

$$s = \frac{a+b+c}{2}$$

Statistics: The statistical data were computed with the statistical package SPSS for windows 13.0J (SPSS Inc., 2005). Descriptive statistics were performed. Paired t-test, independent t-test, and linear discriminant analysis were used to analyze the data. The significance level was considered positive when the p value shows less than 0.05. An unpaired t-test (p-0.05) was done to compare between the right and left parameters in both sexes.

Results

The descriptive statistics comparison of the means and standard deviations of the male and female dried skull bones with sides is depicted in the table no. 1. Upon comparison of all the mastoid parameters in both sexes and sides, the parameters were more in males and on the right side. In case of males the width, height, PA, MA, and PM measurements were higher on the right side than left. Whereas the length of the mastoid process in females was found to be more on the left side by a few millimeters. Also, in females the values were almost equal on the left and right side for all the above parameters.

Table no 3. depict the comparison of each of the mastoid parameter between sides versus gender. Statistical significance was observed in the width in both male and female.

The comparison of the mastoid process parameters observed on right side (Figure 3a) and left side (Figure 3b) parameters in both gender .

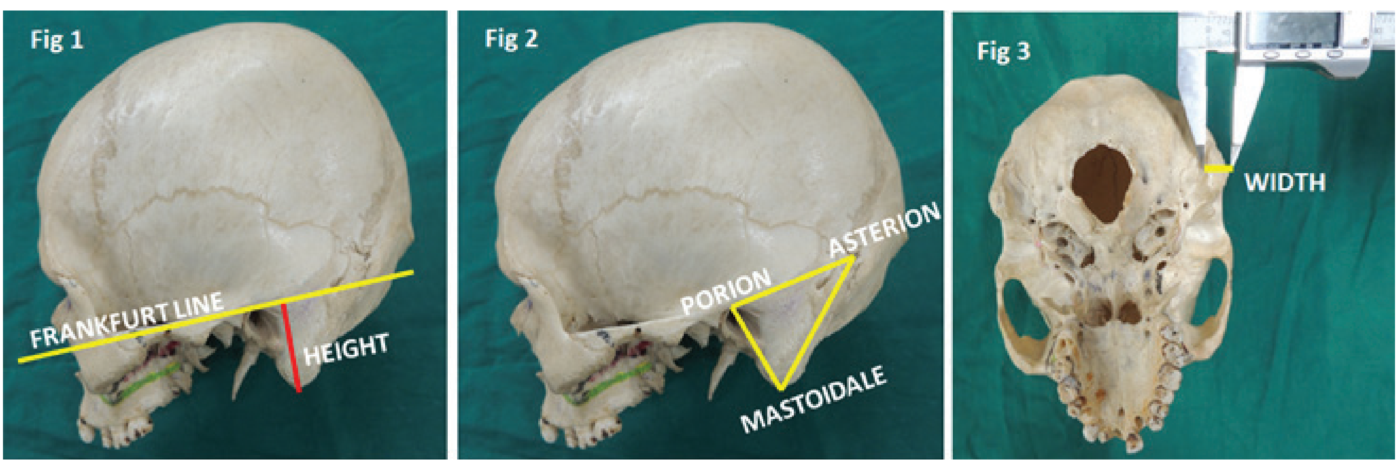

Figure 1.

Table 1. Descriptive statistics comparing the means and standard deviations of male and female dried skull bones with sides.

Parameter	Male				Female			
	Right (n=50)		Left (n=50)		Right (n=50)		Left (n=50)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Height	30.314	3.552	30.098	3.6508	27.392	3.846	26.578	3.3142
Width	13.404	2.418	12.086	2.4843	11.584	2.983	9.33	2.5575
Length	31.9	2.971	32.62	3.9297	28.372	2.890	28.904	3.7982
Porion to Mastoidale (PM)	31.63	3.165	31.55	3.3902	29.12	3.645	27.656	2.7201
Mastoidale to Asterion (MA)	51.7424	4.942	50.892	4.9669	45.728	4.808	44.05	6.8628
Porion to Asterion (PA)	47.67	4.368	46.72	3.9472	42.302	4.474	42.302	3.7651
Half-perimeter	65.522	5.177	64.581	4.9267	58.575	5.383	57.004	4.805
Mastoid triangle area	735.8023	114.662	718.3669	110.1897	598.5663	110.715	564.66	83.96

Multivariate analysis extends the capabilities of variance by assessing multiple dependent variables simultaneously as in table 2, was found to be statistically significant.

Table 2. Multivariate Tests.

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	1.000	32982.982^b	16.000	82.000	.000
	Wilks' Lambda	.000	32982.982^b	16.000	82.000	.000
	Hotelling's Trace	6435.704	32982.982^b	16.000	82.000	.000
	Roy's Largest Root	6435.704	32982.982^b	16.000	82.000	.000
SEX	Pillai's Trace	.459	4.340^b	16.000	82.000	.000
	Wilks' Lambda	.541	4.340^b	16.000	82.000	.000
	Hotelling's Trace	.847	4.340^b	16.000	82.000	.000
	Roy's Largest Root	.847	4.340^b	16.000	82.000	.000

Table 3. Paired sample test of various mastoid parameters in male and female population.

Paired Samples Test										
SEX			Paired Differences					t	df	Sig. (2-tailed)
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
						Lower	Upper			
Male	PM	Right Vs Left	.0800	2.3298	.3295	-.5821	.7421	.243	49	.809
	MA	Right Vs Left	.8500	4.1809	.5913	-.3382	2.0382	1.438	49	.157
	PA	Right Vs Left	.9500	4.5607	.6450	-.3461	2.2461	1.473	49	.147
	Height	Right Vs Left	.2160	2.7825	.3935	-.5748	1.0068	.549	49	.586
	Width	Right Vs Left	1.3180	2.0512	.2901	.7351	1.9009	4.544	49	.000
	Length	Right Vs Left	-.7200	3.5946	.5083	-1.7416	.3016	-1.416	49	.163
Female	PM	Right Vs Left	1.4640	2.9584	.4184	.6232	.4184	3.499	49	.001
	MA	Right Vs Left	1.6780	7.4746	1.0571	-.4463	1.0571	1.587	49	.119
	PA	Right Vs Left	.0000	3.6375	.5144	-1.0338	.5144	.000	49	1.000
	Height	Right Vs Left	.8140	3.2956	.4661	-.1226	.4661	1.747	49	.087
	Width	Right Vs Left	2.2540	2.2340	.3159	1.6191	.3159	7.134	49	.000
	Length	Right Vs Left	-.5320	2.9731	.4205	-1.3769	.4205	-1.265	49	.212

The comparison of the right vs left side parameters of the male mastoid process parameters showed more differences in width, semi-perimeter, and MA are more on the right side whereas the other parameters like the mastoid length, height, PM, and PA are almost equal in both sides (Figure 4a). Similar comparison of the right vs left side parameters in female mastoid process (Figure 4b) showed almost consistent with the result obtained with male mastoid process.

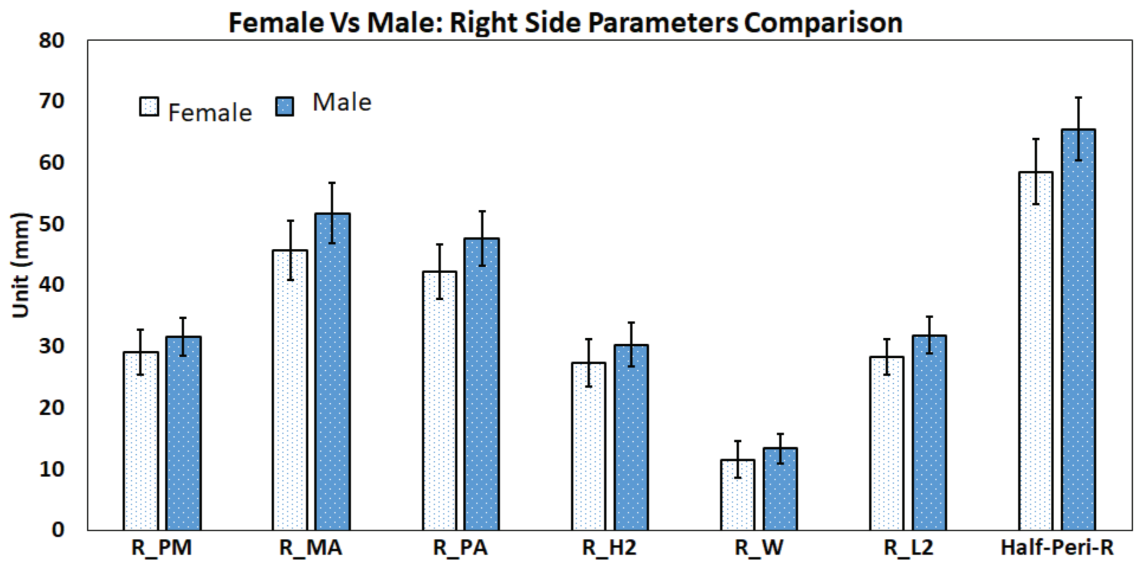

Figure 2.

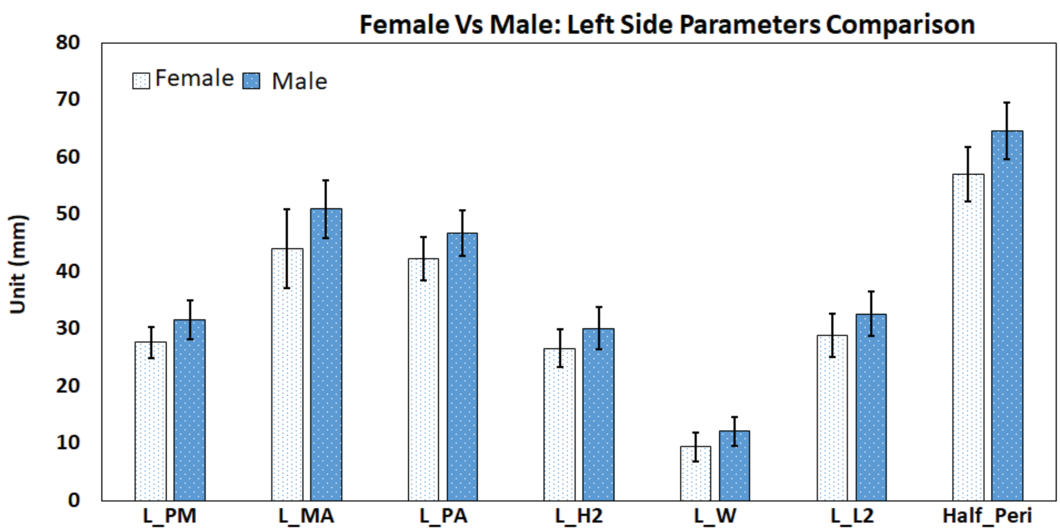

Figure 3.

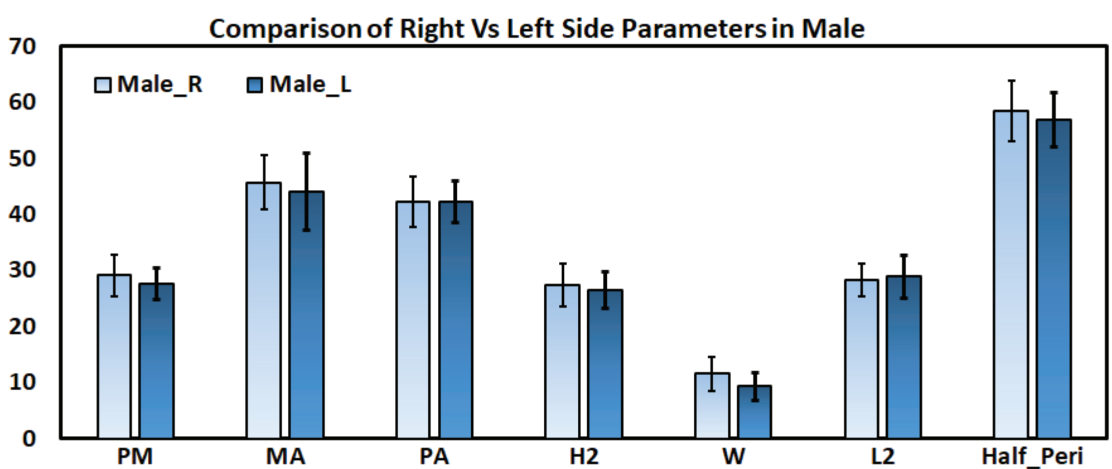

Figure 4.

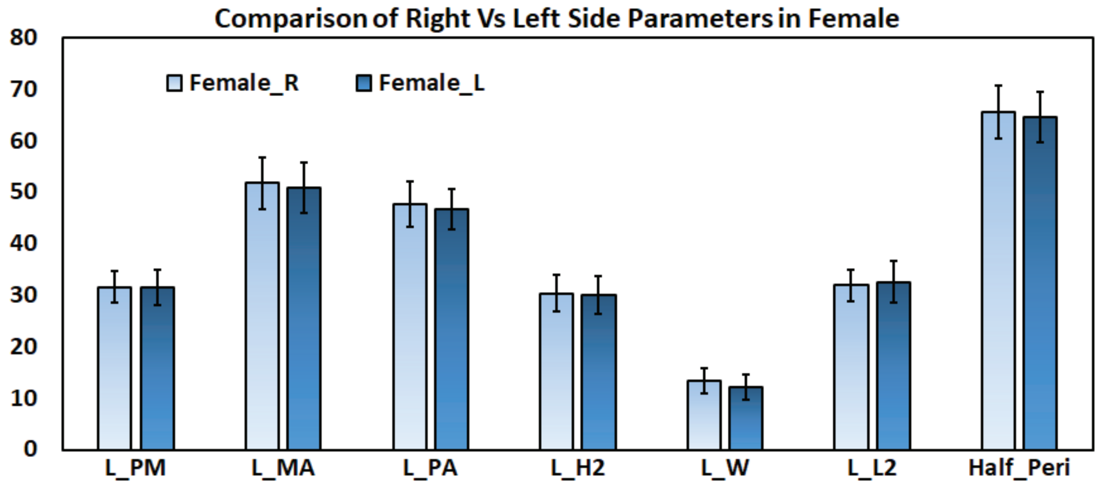

Figure 5.

Discussion

Mastoid region is one of the slowest growing regions of cranium and shows higher degree of sexual dimorphism in adulthood[6,11]. Difference between the size of mastoid process in males and females could be due to variation in the growth of mastoid process due to the stronger pull of the bulkier muscle-sternocledomastoid in male[9,12,13].

The accuracy of the mastoid sex determination with one variable is approximately 80% and reaches 90% with the combination of two or more variables especially with the mastoid process width and the mastoid process height. This statement turns true only when we took careful attention to avoid the measurement errors [14]. In addition, up to 30% of the total error variances while considering the measurements makes the sex determination more complex. The mastoid process length is not a useful variable. This is due to number of reasons like inconsistent asterior landmark, complex lambdoid suture, and the appearance of Wormian bones on the lambdoid suture.

In the present study we have tried to compare the parameters related to mastoid process with different regions of India. The study done by Saini et. al., on 138 adult crania of North Indian population found that ML was 35.823mm and 31.869mm, and MW was 25.582 mm and 22.771 mm in males and females respectively[13]. Study done by Sukare *et al.*, on the morphometric study of mastoid process on Marathwada population found that ML was 25.32 mm 20.17 mm and MW was 21.60mm and 18.21mm in males and females respectively[14]. Roy in his study on East Indian population observed that ML was 27.61mm and 23.87mm in males and females respectively (16, 17). Nidugala's study on South Indian skull bones documented ML as 35.63 and 30. 55 mm and MW 21.97mm and 20.03mm respectively in males and females. In the present study ML was 31.9mm on the right and 32.62mm on the left in case of males. In females ML was 28.37mm on the right side and 28.9mm on the left side[18]. The MW was 13.40mm on the right side and 12.08mm on the left side in males. Whereas in females MW was 11.58mm on the right and 9.3mm on the left side. We have also noted MH which was 30.31mm and 30.09mm on the right and left side respectively in males and 28.37mm and 28.9mm on the right and left side respectively in females.

Many published articles on the mastoid measurement showed variations from 10% to 35% due to their variations in the reference point taken by each author. To bring down the percentage of error to below 10, we have followed the Kouchi & Koizumi criterion which is proved to be 85 to 92% accurate in mastoid measurement[19]. Hoshi H stated that, when the skulls were kept on flat surface, it lies on mastoid process in males and on occipital condyles in females[20]. This observation indirectly confirms that the male skulls have more mastoid length. De Paiva LA, in their study stated that for sex determination MH and MW are more useful than ML[20].

Other parameters related to mastoid process are compared with various authors are tabulated in the table below.

Table 4. Comparison between present study and with studies done by various authors.

Regions of India	No of Skulls	PM		AM		AP	
		Male	Female	Male	Female	Male	Female
North India[13]	138	31.77	27.98	47.83	43.0	47.89	44.69
Western India[15]	132	29.86	25.17	48.33	42.59	44.96	40.46
Eastern India[16]	66	29.56	24.34	49.73	44.15	45.51	42.22
South India[18]	80	29.52	24.26	50.11	46.51	44.48	42.87
Present Study South India	100	31.59	28.39	51.31	44.89	47.19	42.30

The above table infers that the PM and AP lengths of our study is like north Indian population whereas the AM length is similar to south Indian population as noted by Nidagula *et al.*, 2013. The reason for the mastoid parameters in the present study and the Nidagula **et al.**, could be due to the various factors like mastoidale reference point, different methods of measurements, intra and inter observers' variations while marking the reference point, geographical and food habits, and finally, the age of the skull at the time of death.

Ghule and his colleagues in their study on sexual dimorphism of mastoid process had said that mastoid process index was significantly more in females than in males[20]. Similarly, Sukare *et al.*, also had a same opinion that mastoid process index was more in females than in males[15].

Some authors had opinion that there was no significant difference between the measured variables of mastoid triangles on right and left side. But the differences among the geographical regions could be due to the differences in the methodology of different studies differences, inconsistent bony landmarks. Also, due the environment/genetic/nutrition influences in different populations[22,23]. Craniofacial growth like mastoid region, zygomatic process and the ridges of occipital bone are influenced by nutrition, environment, and genetic factors[14].

Conclusion

Finally, it should be noted that sex determination using a mastoid process has some limitations, study on a particular population cannot be generalized to other population. It can be possible to determine the sex of the person whose identity is unknown only if we are aware of the nationality and race of the individual. It is better to conduct a study on a larger statistical population in which age, race, and other factors also taken in to account.

References

1. Sobhani F, Salemi F, Miresmaeili A, Farhadian M. Morphometric analysis of the inter-mastoid triangle for sex determination: Application of statistical shape analysis. Imaging Sci Dent. 2021 Jun;51(2):167-174. doi: 10.5624/isd.20200297. Epub 2021 Feb 9. PMID: 34235062; PMCID: PMC8219444.
2. Balci Y, Yavuz M, Ca ğdir S. Predictive accuracy of sexing the mandible by ramus flexure. Homo. 2005;55(3):229-37.
3. Krogman, W.M. and Iscan, M.Y. (1986) The Human Skeleton in Forensic Medicine. 2nd Edition, Charles C. Thomas, Springfield.
4. Robinson MS, Bidmos MA. An assessment of the accuracy of discriminant function equations for sex determination of the femur and tibia from a South African population. Forensic Sci Int. 2011; 206:212. e1e5.
5. Wahl J, Henke W. The pars petrosa as diagnostic aid in multivariate biometric sex determination of creamated human remains]. Z Morphol Anthropol. 1980;70(3):258-68. German. PMID: 7415403.
6. Humphrey LT. Growth pattern in modern human skeleton. Am J Phys Anthropol 1998; 105:57–72.
7. Farhadian M, Salemi F, Shokri A, Safi Y, Rahimpanah S. Comparison of data mining algorithms for sex determination based on mastoid process measurements using cone-beam computed tomography. Imaging Sci Dent. 2020 Dec;50(4):323-330.
8. Rogers TL. Determining the sex of human remains through cranial morphology. J Forensic Sci 2005; 50: 493–500
9. Suazo GIC, Zavando MDA, Smith RL. Performance evaluation as a diagnostic test for traditional methods for forensic identification of sex. Int J Morphol 2009;27(2):381–6.
10. https://en.wikipedia.org/wiki/Heron%27s_formula
11. Enlow DH. The human face: an account of the postnatal growth and development of the craniofacial skeleton. New York, NY: Hoeber Medical Division, Harper & Row Publishers, 1968.
12. Franklin D, Freedman L, Milne N, Oxnard CE. A geometric morphometric study of sexual dimorphism in the crania of indigenous southern Africans. S Afr J Sci 2006; 102:229–38.
13. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK. Sex estinmation from the mastoid process among north Indians. J Forens Sci 2021; 57 (2): 434-9. Doi.org: 10.1111/j.1556-4029.2011. 01966.x.
14. 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. Anthropol Sci 2008;116(2):105–13.
15. Passey J, Pandey S, Singh R, Singh S. Morphometric Study of the Mastoid Triangle for Sexual Dimorphism of Dry Skulls in the North Indian Population. Cureus. 2021 May 5;13(5):e14859. doi: 10.7759/cureus.14859. PMID: 34113497; PMCID: PMC8177990.
16. Roy K, Mukhopadhyay PP. Predicting Sex from the Linear Measurements of Mastoid Process: A Preliminary Study in Skulls of Eastern Indian Population. Indian J Foren Med Toxicol 2019; 13(3): 66
17. Ghule SB, Mahajan AA,Wagh KB, Ambali MP. Sexual dimorphism in foramen magnum and mastoid process. International jr of recent trends in science and technology 2014; 12(1):56-9
18. Sharma BB, Nidugala H, Avadhani R. Mastoid process a tool for sex determination, an anatomical study in south Indian skulls. Int Jour of Biomed Res 2013;4(2):106-10.
19. Makiko K and Koizumi K. An analysis of errors in craniometry. J Anthropol Soc Nippon 1985; 93(4): 409-424.
20. de Paiva LA, Segre M. Sexing the human skull through the mastoid process. Rev Hosp Clin Fac Med Sao Paulo. 2003 Jan-Feb;58(1):15-20
21. Rogers TL. Determining the sex of human remains through cranial morphology. J Forensic Sci. 2005 May;50(3):493-500. PMID: 15932077.
22. Amin W SM-W, Othman D, Thunaibat H. Osteometric assessment of the mastoid for sex determination in Jordanians by discrimination function analysis. Am J Med Biol. 2015;3(4):117-23.
23. Madadin M, Menezes RG, Al Dhafeeri O, Kharoshah MA, Al Ibrahim R, Nagesh K, *et al*. Evaluation of the mastoid triangle for determining sexual dimorphism: A Saudi population-based study. Forensic Sci Int. 2015 Sep; 254:244. e1-4. doi: 10.1016/j.forsciint.2015.06.019.

Mini Curriculum and Author's Contribution

1. Hosapatna Mamatha, MBBS; MD: Contribution: Effective scientific & intellectual participation for the studt, technical procedures, data requisition, data interpretation, preparation & draft of manuscript, critical review & final approval. ORCID: 0000-0002-7150-1369

2. Kumar MR Bhat, PhD; Contribution: preparation & draft of manuscript, critical review & final approval.

3. Vishwanath Managuli, MTech; PhD: Contribution: critical review & statistics. ORCID: 0000-0003-1593-8897

4. Prasanna LC, MD; DNB: Contribution: preparation & draft of manuscript, critical review & final approval. Orcid: 0000-0002-0737-9573

Received: January 23, 2023
Accepted: March 3, 2023

Corresponding author
Lokadolalu Chandrachar Prasanna
E-mail: prasanna.lc@manipal.edu