Original Article

Assessment of Sexual Dimorphism Using External Ear Morphometry: A Cross-Sectional Study Among Adults in Bardhaman, West Bengal

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Abstract

Introduction: The sexual dimorphism based on morphometric ear variables of the adult Indian population is highly under-explored. Morphometry of external ear from other countries cannot be directly applicable to the Indian population.

Aims and Objectives: This study aimed to evaluate morphometric parameters of the external ear among adult Bengali population to assess sex-based differences.

Materials and Method: A descriptive, cross-sectional study was conducted at the Burdwan Medical College and Hospital from March 2021 to March 2022, involving 146 males and 146 females. Right (RT) and Left (LT) Auricle length (AL), Auricle Width (AW), Lobule Length (LL), and Lobule Width (LW) were measured using vernier calipers. Auricle Index (AI) and Lobule Index (LI) were calculated. Two-tailed paired t-test was performed between the corresponding variables of males and females.

Result: Right Auricle Length (RTAL), Auricle Width (RTAW), Lobule Length (RTLL), Lobule Width (RTLW) and Lobule Index (RTLI) showed significant sexual dimorphism. Left Auricle Width (LTAW), Lobule Length (LTLL) and Lobule Width (LTLW) also showed significant differences ($p < 0.05$).

Conclusion: The result suggests significant sexual dimorphism in external ear morphometry among the Bengali population. The assessment of ear morphometry using a simple and direct technique can be useful during forensic investigations. These preliminary findings indicate that ear morphometry can be used as a supportive tool in forensic anthropology and biometric identification.

Keywords: Sexual Dimorphism, Ear Morphometry, External Ear, Biometric Identification, Bengali Population, Forensic Anthropology Assessment of Sexual Dimorphism Using External Ear Morphometry: A Cross-Sectional Study Among Adults in Bardhaman, West Bengal.

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Introduction

Auricle (Pinna)[1] is the external part of the ear (Fig.-1), projected on the side of the head. It collects sound waves and conducts them towards the tympanic membrane[2].

The auricle has two surfaces - lateral and medial[3]. On the irregular lateral surface, a triangular projection called the tragus, and an elevation - antitragus are separated by an intertragic notch[4] (Fig. – 1). The soft and flexible lobule of the ear hangs below the antitragus[4].

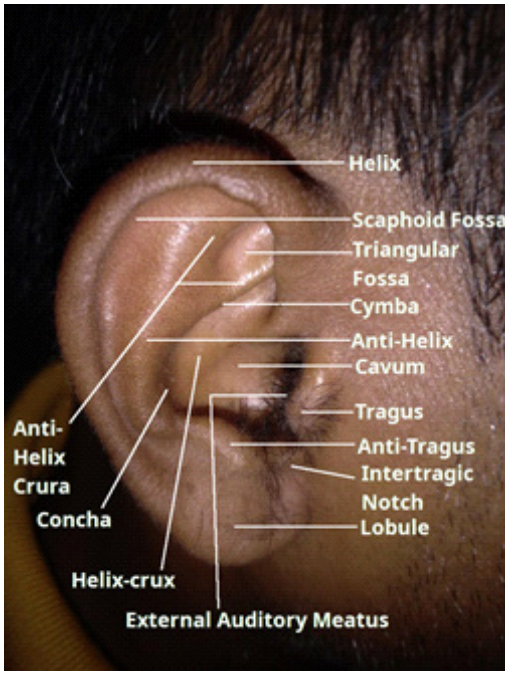

Figure 1: Parts of the External Ear

The auricle is very significant in various religions and cultures, this reflects its anthropological and ethnic importance across populations[5,6]. The ear lobule is of considerable interest in cosmetic and reconstructive practices, including advances in tissue-engineered reconstruction[7].

Studies have shown that external ears exhibit metric variations depending on gender and ethnicity[8,9,10]. Ethnic variations necessitate the availability of population-specific data[11]. Morphometric data of the external ear from other populations is less likely to be applicable to Indians. Few studies on sex determination from ear morphometry in the Indian population are available [12,13]. Studies describing the morphometry of ear auricles in the Indian female population are hardly available [14,15]. One reason for this can be that most of the studies have excluded subjects on the basis of ear piercing[13].

The importance of ear piercing holds social, religious, and aesthetic significance in India. The practice of Karnavedha sanskar, a traditional Hindu ceremony of ear piercing is very rampant[15]. This cultural aspect needs to be considered while studying ear morphometry.

While some authors have employed direct anthropometry[16] , a study conducted in Karnataka employed photogrammetric method to explore sex determination potential using ear morphometry for the Indian population[17]. Since studies based on ear morphometry are sparsely conducted in the adult Bengali population, there is a gap in region-specific anthropometric data. The present study aims to address this issue.

It is expected that the conclusive data will be useful in the fields of forensic science, prosthetics, surgery, anatomy, and even wearable technology[11,16,18,]. Ear morphometric parameters can be utilized during auricular reconstruction surgery[19] and as an adjunct to other methods used for individual human identification [5,11,16].The data from the present study can be utilised to compare previous work related to sexual dimorphism from other countries[20] as well among different ethnic zones of India for demographic and anthropological research [5,18].

Materials and Method

Method--This descriptive cross-sectional study was conducted for a period of one year from March 2021 to March 2022 at the Burdwan Medical College and Hospital (opd)

Ethical Clearance--Ethical approval for the study was obtained from the Institutional Ethics Committee of Burdwan Medical College and Hospital (Ref. No. BMC/I.E.C-077, dated 22.02.2021). Written informed consent was obtained from each participant.

Conflict of interest/ funding-- none

Sample Size---A sample size of 584 ears was calculated based on mean and standard deviation values (Mean: 54.01 mm, SD: 4.69 mm) [5], using the

formula n = ($Z^2 \times SD^2$) / d^2 with a 99% confidence level (z = 2.576) and 0.5 mm precision.

Sampling technique--Simple Random sampling, random numbers were generated using an online randomizer (Randomizer.org).

Inclusion Criteria--1.Healthy adults aged between 18 and 60 years. 2. Permanent residents of Bardhaman district. 3.Willing to provide written informed consent

Exclusion Criteria--1. Individuals with visible congenital deformities of the external ear. 2. History of trauma or surgery affecting the ear. 3. Individuals with ear infections or skin diseases affecting the auricle. 4. Participants refusing consent.

Data Collection and Measurement Techniques--Anthropometric measurements were carried out in a well-lit room with the subject seated comfortably and the head in the Frankfort horizontal plane[21].

Masks, earrings, spectacles were removed, if present. The morphometric parameters were recorded with the subject in a seated position with the head in the Frankfort horizontal plane, using digital vernier calipers (Fig. 2).

To minimise human errors, all the subjects were seated in the same chair, kept in a fixed position and distance from the wall in front. They were asked to focus their gaze at the marked point on the front wall. All the parameters were measured twice for every individual. And all the measurements were taken by the same investigator using the same digital vernier caliper, in the same way, throughout the study duration to eliminate inter-observer variability. All the measurements were taken between 9 AM to 1 PM (OPD hours).

A] The following parameters were measured and collected (independently for right and left side):

i) Auricle length (AL): largest perceived length measured from the uppermost point (on the helix) of the auricle up to the lowest point on the ear lobule.

ii) Auricle width (AW): widest perceived measurement from the attachment (root) of the auricle to maximum convexity of the helix.

iii) Lobule length (LL): the largest distance from the lowest point of free margin of the ear lobule to the line passing through the intertragal notch.

iv) Lobule width (LW): from the line passing through the intertragal notch to outermost maximum transverse width of the ear lobule.

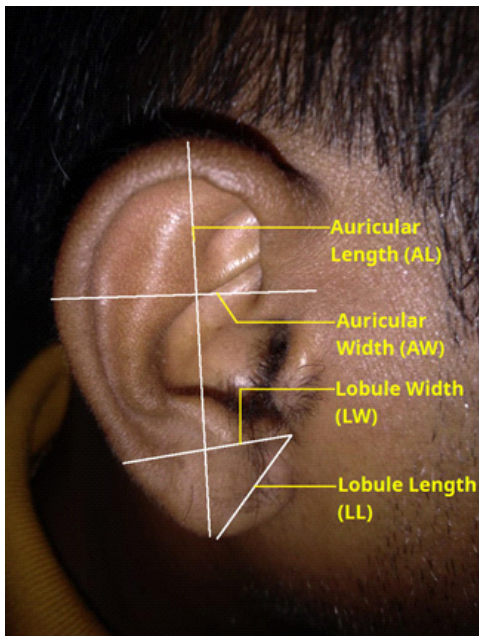

Figure 2: Study Variables measured in this study

b] Auricle index (AI) percentage ratio of width and length of an auricle, and Lobule Index (LI) percentage ratio of width and length of lobule were calculated.

[Auricle Index (AI) = (AW/AL) × 100, Lobule Index (LI) = (LW/LL) × 100]

c] The Mean and Standard deviation of all the variables measured during morphometry of left and right ears of men and women were calculated. Sexual dimorphism was assessed using two-tailed Student's t-test at the 95% confidence interval, comparing right and left ear measurements between the sexes.

d] Data entry and statistical analysis: Microsoft Office 365 Excel.

Results and Analysis

For the sample size of 584 ears, after morphometry, the data was recorded in 2 different tables: Men and Women. The auricular and lobular indices were calculated for men and women. The indices showed the proportions of the auricles and lobes. These tables have been attached in the Master charts.

The Mean and Standard deviations: All the mean and standard deviation values of morphometric variables of Men were found to be greater than Women except for Left Auricle Index which was marginally bigger in women 53.53 +/- 4.33 as compared to men 53.42 +/- 4.5.

Overall Mean Values: Some authors have described the overall mean values of the morphometric variables. In order to compare the data of present study with them, the overall mean values of the corresponding variables of external ears of men and women who participated the study were calculated. VARIABLE and AVERAGE: AL = 59.61, AW = 32.28, LL = 28.57, LW = 25.89, AI = 54.26, LI = 91.02

Right Ear

The t-test and p-values of all the variables of the right ear of men and women were calculated and compared for significance, namely the Right Auricle Length (AL)-9.26, Auricle Width (AW) 9.10, Auricle Index (AI)-1.06, Lobule Length (LL)-4.64, Lobule Width (LW)-7.03 and Lobule Index (LI)-2.47. All the t values and p values were significant except for the Auricle Index (AI) (Table 1). Thus there is a significant difference between all the variables of right ears of men as compared to women except the Auricle Index (AI). (p-value <0.05) (Figure 3)

Table 1: Two tailed paired t-test performed between the corresponding variables of the right ear auricles of Men and Women. (Author's own analysis)

SEX	VARIABLE	t-test	p-value	RESULT
MEN	RT AL	9.26	< .00001	Sig
WOMEN	RT AL			
MEN	RT AW	9.10	< .00001	Sig
WOMEN	RT AW			
MEN	RT LL	4.64	< .00001	Sig
WOMEN	RT LL			
MEN	RT LW	7.03	< .00001	Sig
WOMEN	RT LW			
MEN	RT AI	1.06	0.29	NONSIG
WOMEN	RT AI			
MEN	RT LI	2.47	0.01	Sig
WOMEN	RT LI			

[RT=RIGHT, LT=LEFT, AL=AURICLE LENGTH, AW= AURICLE WIDTH, LL=LOBULE LENGTH, LW=LOBULE WIDTH, AI= AURICLE INDEX,

LI=LOBULE INDEX, SIG=SIGNIFICANT, NONSIG=NONSIGNIFICANT, SD= STANDARD DEVIATION. (p value <0.05)]

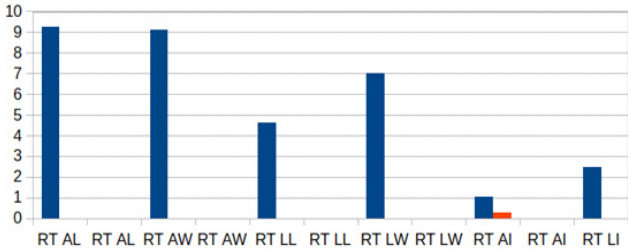

Figure 3: Two-tailed paired t-test results for right ear variables (Author's own analysis)

Left ear

When the variables of the left ears of Men and women were compared using paired, two tailed T test, it was found that the Left Auricle Length (AL)1.09, Auricle Index (AI) -0.78211 and Lobular Index (LI) 0.96 did not show any significant difference. The other values namely, the Left Auricle Width (AW) 7.4, Lobular Length (LL) 2.2, Lobular Width (LW) 2.7 show a significant difference between men and women. (p-value <0.05), (Table 2, Figure 4)

Table 2: Two tailed paired t-test performed between the corresponding variables of the left ear auricles of Men and Women.(Author's own analysis)

SEX	VARIABLE	t-test	p-value	RESULT
MEN	LT AL	1.09	0.28	NONSIG
WOMEN	LT AL			
MEN	LT AW	7.4	< .00001	Sig
WOMEN	LT AW			
MEN	LT LL	2.2	0.03	Sig
WOMEN	LT LL			
MEN	LT LW	2.7	0.01	Sig
WOMEN	LT LW			
MEN	LT AI	-0.78211.	0.43	NONSIG
WOMEN	LT AI			
MEN	LT LI	0.96	0.34	NONSIG
WOMEN	LT LI			

[RT=RIGHT, LT=LEFT, AL=AURICLE LENGTH, AW= AURICLE WIDTH, LL=LOBULE LENGTH, LW=LOBULE WIDTH, AI= AURICLE INDEX, LI=LOBULE INDEX, SIG=SIGNIFICANT, NONSIG=NONSIGNIFICANT, SD= STANDARD DEVIATION. (p-value <0.05)]

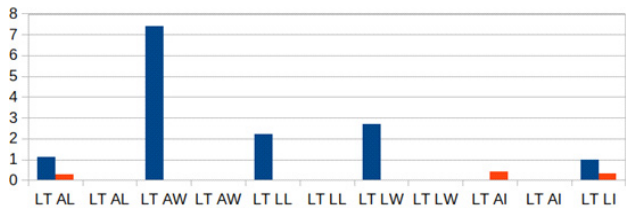

Figure 4: Two-tailed paired t-test results for left ear variables (Author's own analysis)

The present study suggests that significant sexual dimorphism exists in several external ear morphometric parameters among the adult Bengali population (Table 3).

Table 3: Comparative Summary of Right and Left Ear Sexual Dimorphism (Author's own analysis)

SEX	VARIABLE	RIGHT EAR	LEFT EAR
MEN	LT AL	Sig	NONSIG
WOMEN	LT AL		
MEN	LT AW	Sig	Sig
WOMEN	LT AW		
MEN	LT LL	Sig	Sig
WOMEN	LT LL		
MEN	LT LW	Sig	Sig
WOMEN	LT LW		
MEN	LT AI	NONSIG	NONSIG
WOMEN	LT AI		
MEN	LT LI	Sig	NONSIG
WOMEN	LT LI		

Discussion

Brucker et al[22] observed that men had larger auricles than women by 6.5%, whereas lobule dimensions were nearly equal. In the present study, mean auricle length was greater in men than in women, and lobule measurements also showed variation between sexes.

Azaria et al.[23] reported average lobule lengths to be 19.7 mm (SD 4.2) on the left and 20.1 mm (SD 4.2) on the right. In comparison, our study found right and left lobule length in men to be 30.02 mm (SD 3.2) and 28.3 mm (SD 3.07), and in women, 28.39 mm (SD 2.71) and 27.58 mm (SD 2.47), respectively. This suggests that individuals from Bardhaman, West Bengal have longer earlobes than populations in Israel, America, Turkey, Nigeria, and China[6,25–30]. Previous studies have generally reported larger morphometric values in males, a trend that is supported by this study [26].

Some studies utilised direct morphometry with vernier calipers[10, 17], while others preferred indirect method of morphometry [11,18] (photographic methods or 3-D scanning). In this study, digital vernier calipers

were used as a direct method—an easily portable and low-maintenance tool suitable for field research.

According to Purkait and Singh[24] noted that lobule shape and attachment influence its dimensions. Other studies also found that sex and age affect lobular length[26, 27].

Bozkir et al concluded that men had larger height of the pinna than women by 6.5% in the Turkish population[6]. Neimitz[26] et al from Germany and Murgod[17] in Karnataka, India used indirect morphometry and concluded that sexual dimorphism existed among various parameters of the external ear. Maitreyee M also concluded that sexual dimorphism could be seen in all parameters especially, auricle length and width[5]. They also considered auricle attachment and projection, face height and width[5].

In a recent study, Acharya et al. also observed significant sexual dimorphism in external ear morphology in Indian population, which further supports the forensic applicability of ear morphometry[14]. Ekanem et al[27] and Mustapha et al pointed out that sexual dimorphism exists in the Nigerian population[29]. Wang (2010) did not find any significant differences between the ear measurement of males and females[28]. Whereas, the present study begs to differ with Wang, but agrees with the findings of Brucker, Mutalik and with Mustafa that morphometric variables of ear auricles do show sexual dimorphism.

In the 19th century Alphonse Bertillon utilized ear auricle morphometry using his system called as "portrait parlé" [33] or spoken portrait for forensic human identification.

In Brazil, after a prison riot leading to several mangled body parts, a beheaded corpse could not be identified with usual forensic methods. In such situation, ear morphometry can be utilised when other anatomical features are missing for forensic identification[34].

To be useful for identification, biometrics should be constant, unique and easy to acquire in nature[35]. The identification features used so far as biometrics are face and iris scan, fingerprints detection, voice recording and manual signature. During the Covid-19 pandemic, wearing mask was mandatory making identification difficult. The external auricle provides a good source of data for person identification which can be contactless, quick and simple. Ear biometry achieved using simple CCTV camera surveillance (even when mask on) can be used for identification in public places, it does not require cooperation from the subject[36].

Conclusion

The study suggests significant sexual dimorphism in external ear morphometry among the adult Bengali population. However, there was an absence of significant dimorphism in Left Auricle Index and Lobule Index, as compared to their right-sided counterparts. This points toward potential auricular asymmetry, which is a novel and unexpected finding. This not only emphasizes but also highlights the need to include both ears in biometric analyses. Further research is required to establish whether correlation exists between the asymmetry and ethnic, genetic or socioeconomic factors.

Limitations: This study is limited to a specific regional population. As such, the results may not be generalisable to all Indian ethnic groups. The inclusion of individuals with pierced ears may also limit applicability across broader population. In future, meta-analysis targeting diverse Indian populations is recommended. Additional morphometric variables such as conchal width and length, distance between intertragic notch and tragus, the angle of projection of auricle, etc should also be considered. This may provide more precise estimation of sexual dimorphism. Longitudinal studies may help to understand the morphometric changes across different age groups.

Furthermore, the morphology of external ear needs to be correlated with its morphometry. Advanced technology offers faster and more precise resultsas compared to manual morphometry. This point of view is very crucial while comparing data obtained through manual methods versus computer-based morphometry. Nonetheless, the use of handheld vernier calipers is a noninvasive and economical method suitable for carrying out forensic investigations, even in resource-limited settings in remote areas. This study suggests that ear morphometry can be used as a supportive tool during

forensic anthropology, biometric identification and various medico-legal applications. In conclusion, this study shows promising avenues for conducting multi-ethnic, ear morphometry based studies incorporating 3D scanning for accurate and reliable ear based human identification.

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Source of funds: Self.

Conflict of interest: Nil

Ethical clearance: Obtained from Institutional Ethics Committee, Burdwan Medical College, Purba Bardhaman, West Bengal. Memo no.BMC/IEC/077 Dated- 22nd Feb 2021.

References

1. Merriam-Webster. Ear [Internet]. Merriam-Webster. com; 2025 [cited 2025 Jul 8]. Available from: https:// www.merriam- webster.com/dictionary/ear
2. Datta AK. Essentials of human anatomy: head and neck. Kolkata: Current Books International; p. 317–46.
3. Gleeson M. External and middle ear. In: Standring S, editor. Gray's anatomy: the anatomical basis of clinical practice. 41st ed. London: Elsevier; 2015. p. 624–39.
4. Singh V. Textbook of anatomy: head, neck, and brain. Vol. 3. 2nd ed. New Delhi: Elsevier; p. 252–72.
5. Maitreyee M. Analysis of morphometric and somatoscopic traits of auricle of ear in India: relation with diversified ethnicities. J Exp Clin Anat. 2019;18(1):1.
6. Bozkır MG, Karakaş P, Yavuz M, Dere F. Morphometry of the external ear in our adult population. Aesth Plast Surg. 2006;30(1):81–5.
7. Cao Y, Vacanti JP, Paige KT, Upton J, Vacanti CA. Transplantation of chondrocytes utilizing a polymer-cell construct to produce tissue-engineered cartilage in the shape of a human ear. Plast Reconstr Surg. 1997;100(2):297–302.
8. Pupovac N, Knežić N. Morphometry of the auricle. Medicina Danas. 2017;16(7–9):117–23.
9. Mohamed H, Adly M, Abuelhamed M. Determination of Sex in Minia Government using External Ear Print Measurements [Internet]. 2018 Jul 5 [cited 2025 Jul 9]. Available from: https://www.researchgate.net/ publication/326200334_ Determination_of_Sex_in_ Minia_Government_using_ External_Ear_Print_ Measurements
10. Kumar BS, Selvi GP. Morphometry of ear pinna in sex determination. Int J Anat Res. 2016;4(2):2480–4.
11. Britto J, Panchal P, Prasad A, Kumari R, Kumari S. Photogrammetric morphometric analysis of auricle. Int J Med Sci Public Health. 2018 Jun 1;7(6):440-3.
12. Sharma A, Sidhu NK, Sharma MK, Kapoor K, Singh B. Morphometric study of ear lobule in northwest Indian male subjects. Anat Sci Int. 2007;82(2):98–104.
13. Verma P, Sandhu HK, Verma KG, Goyal S, Sudan M, Ladgotra A. Morphological variations and biometrics of ear: an aid to personal identification. J Clin Diagn Res. 2016;10(5):ZC138.
14. Acharya S, Gupta C, Palimar V, Kalthur SG, Adhikari P. Morphology and morphometry of human external ear with its significance in sex determination and stature estimation: an observational study. F1000Res. 2025;14:119.
15. Dattatraya JS. Study of Karnavedhana: ancient and contemporary methods. Int Ayurvedic Med J. 2021;9(5):947–51.
16. Purkait R. Progression of growth in the external ear from birth to maturity: a 2-year follow-up study in India. Aesth Plast Surg. 2013;37(3):605–16.
17. Murgod V, Angadi P, Hallikerimath S, Kale A. Anthropometric study of the external ear and its applicability in sex identification: assessed in an Indian sample. Aust J Forensic Sci. 2013;45(4):431–44.
18. Kala AC, Rajoria S, Agarwal CK, Raj S. Comparative assessment of external ear: morphometric study and sexual dimorphism in medical students in SMS Medical College, Jaipur. J Med Sci Clin Res. 2019;7(5):7406–10.
19. Jagriti R, Raju. Morphometric analysis of the human ear, examining its sexual dimorphism in medical students. Med Innov. 2023;12(2):58–62.
20. Sezgin N, Ersoy G. Metric and morphological features of the ear in sex classification. Egypt J Forensic Sci. 2023;13:44.
21. Richards J. What is the Frankfort plane? [Internet]. NutriActiva Blog; 2024 [cited 2025 May 27]. Available from: https://nutriactiva.com/blogs/ anthropometry/ what-is-the-frankfort-plane

22. Brucker MJ, Patel J, Sullivan PK. A morphometric study of the external ear: age- and sex-related differences. Plast Reconstr Surg. 2003;112(2):647–52.
23. Azaria R, Adler N, Silfen R, Regev D, Hauben DJ. Morphometry of the adult human earlobe: a study of 547 subjects and clinical application. Plast Reconstr Surg. 2003;111(7):2398–402.
24. Purkait R, Singh P. Anthropometry of the normal human auricle: a study of adult Indian men. Aesth Plast Surg. 2007;31(4):372–9.
25. Elyasi L, Araban S, Eftekhar Vaghefi SH. Auricle morphometry in Iranian population. Anat Sci J. 2020;17(2):47–54.
26. Niemitz C, Nibbrig M, Zacher V. Human ears grow throughout the entire lifetime according to complicated and sexually dimorphic patterns: conclusions from a cross-sectional analysis. Anthropol Anz. 2007;65(4):391–413.
27. Ekanem AU, Garba SH, Musa TS, Dare ND. Anthropometric study of the pinna (auricle) among adult Nigerians resident in Maiduguri metropolis. J Med Sci. 2010;10(6):176–80.
28. Wang B, Dong Y, Zhao Y, Bai S, Wu G. Computed tomography measurement of the auricle in Han population of north China. J Plast Reconstr Aesthet Surg. 2011;64(1):34–40.
29. Mustapha M, Firdausi Y, Miko A. Sex discrimination potential of morphometric ear variables among Hausa adolescents in Zaria, Northwestern Nigeria. Niger J Sci Res. 2016;15(3):63–7.
30. Alexander KS, Stott DJ, Sivakumar B, Kang N. A morphometric study of the human ear. J Plast Reconstr Aesthet Surg. 2011;64(1):41–7.
31. Nyemb PMM, Sankale AA, Ndiaye L, Ndiaye A, Gaye M. Morphometric study of the outer ear in young adults. Pan Afr Med J. 2014;19:355.
32. Fakorede ST, Adekoya KO, Fasakin TP, Odufisan JO, Oboh B. Ear morphology and morphometry as potential forensic tools for identification of the Hausa, Igbo and Yoruba populations of Nigeria. Bull Natl Res Cent. 2021;45(1):205.
33. Bertillon A. Identification anthropométrique: instructions signalétiques [Internet]. Melun: Imprimerie administrative; 1893 [cited 2025 Jul 8]. Available from: http://archive.org/details/identificationa00bertgoog
34. Carvalho GP, Bantim YCV. Inmates beheaded in a Brazil prison riot: human identification by ear individual signs. J Forensic Leg Med. 2019;68:101870.
35. Thales Group. Biometrics: definition, use cases, latest news [Internet]. 2023 [cited 2025 May 28]. Available from: https://www.thalesgroup.com/en/markets/digital-identity-and-security/government/inspired/biometrics
36. Ahila Priyadharshini R, Arivazhagan S, Arun M. A deep learning approach for person identification using ear biometrics. Appl Intell. 2021;51(4):2161–72.